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The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Contents

	PAGE.
The Entrance to Industry—II	77
Discussion by Correspondence	77
Non-Magnetic Cast Iron in the Electrical Industry	78
Correspondence	78
Catalogue Received	78
The Viscosity of Cupola Slags in Molten State	79
Waste-Wax Casting	80
Some Notes on Ingot Moulds	81
Suggestions for Research on Steel Castings	83
Brussels International Foundry Conference	84
Oxy-Acetylene Welding	84
Relationships in Cast-Iron Test Results	85
The Institute of Metals	87
A Note on the Influence of Temperature Gradients in the Production of Steel Castings	88
Aluminium Alloys	90
Company Meeting	90
Tungsten Plating	90
This Week's News in Brief	92
Trade Talk	92
Obituary	92
Personal	92
Contracts Open	92
Publication Received	92
New Companies	92
Welded Battleships	92
Raw Material Markets	94
Company Reports	94
Copper in Malleable and Grey Cast Iron	94

The Entrance to Industry—II

Continuing our examination of the proposals referred to in our issue of July 18, and advanced by Political and Economic Planning, the vital importance to industry and the community of the years 14 to 18 is stressed, especially as, with an ageing population, the proportion of those entering industry between these ages is bound to diminish. If, they suggest, there is an unemployment problem, it is better to take these young people off the labour market. A policy to cover this period should ensure some educational influence over the whole period, should supervise health, and should introduce an organised system of industrial recruitment, training and welfare supervision. On the first point the extension of the school-leaving age to 15 is advocated, with compulsory half-time attendance from 15 to 18. The former step is already envisaged under the Hadow Scheme. The half-time attendance in the latter step appears to be based on the idea that the shorter periods, such as that laid down in the Fisher Act, never put into operation, are difficult to arrange for in industry. If young people have to attend half-time, the disorganisation is met by employing two instead of one, so that one is always at the works while the other is in school. But surely this does not deal with the situation, because there are clearly not enough young people available to permit such a plan. Furthermore, such a proposal clearly regards industrial work as wage-earning pure and simple, whereas many young people between these ages are being specifically raised for occupations in which double the numbers could not be absorbed, even if they were available. The proposed policy is suggested for adoption over ten or twenty years, but the arrangements regarding extended schooling are suggested for adoption in stages by 1940, resulting in absorption of half-a-million unemployed by that year. On the vital question of cost, a full year of operation is estimated to cost about thirty millions. Maintenance allowances to young people between 15 and 18 would increase it, but about twenty millions now spent on unemployment benefit and assistance could be credited to the total. To such bold proposals employers, through their properly-constituted bodies, should have alternatives, for one of the principal arguments of those who want to raise the school-leaving age is not its intrinsic desirability, but its favourable reaction on the hard core of unemployment—the two million residue left even in a period of good trade.

Discussion by Correspondence

As we forecast before the Sheffield Conference of the Institute of British Foundrymen, insufficient time was allowed for adequate discussion of the various Papers. There is always a fear amongst the organisers that a Paper may be presented and "fall flat," but our personal experience of the last fifteen conventions or so is amply sufficient to allay any such trepidations. Then, some are of opinion that a limited discussion at the conference is of minor importance because, if of outstanding interest, the Paper can be re-presented before the Branches for further study. This is something of a fallacy, because the value of a discussion is invariably enhanced when the participants are drawn from the widest possible area. Hence the necessity and justification for international conferences, joint meetings of branches, and foreign exchange Papers. Although Dr. Hatfield expressed some disappointment at the absence of ingot-mould makers from the session at which Dr. Swinden and Mr. Bolsolver presented their Paper, yet the discussion was eminently satisfactory from the dual aspects of technological and geographical interest. On the former side, useful contributions were made by both scientific metallurgists and practical foundrymen, whilst from the latter aspect only a representative of the South Wales trades was missing, as speakers were present from all the other ingot-mould-making areas. The organising committee of the Sheffield Conference and the Literary Committee of the Institute may feel that circumstances were against them. Obviously, a reduction in the number of the Papers submitted offers no remedy, as a fair number is an essential to command the presence of executives from other districts, and there are but twenty-four hours in a day! These committees, especially the former, did a vast amount of work of a sterling character, and it is now up to the rest of the membership, and indeed the whole of the foundry industry, to show their appreciation of the technical worth of the Papers submitted by sending along either to the secretary, Mr. T. Makemson, St. John Street Chambers, Deansgate, Manchester, or to us, written discussions upon the Papers which were presented, and which either have already been printed in our columns or will be very soon.

XUM

Non-Magnetic Cast Iron in the Electrical Industry

In the construction of electrical plant and machinery it frequently happens that metallic structural components are used in positions where they are exposed to the influence of fluctuating or alternating magnetic fields. The influence of such fields on the common materials of construction is to produce serious losses and over-heating, firstly on account of the magnetic hysteresis effect in the magnetic metals, and secondly on account of the eddy currents set up.

Hysteresis losses are a function of the magnetic properties of the metal used and may be minimised or eliminated by the use of non-magnetic metals. Eddy-current losses, on the other hand, are closely related to the electrical resistance of the metal in question, and to minimise these it is essential to maintain a high electrical resistance. Many of the non-ferrous alloys such as the brasses and bronzes satisfy the first of these conditions, but their electrical resistance is low and they therefore fail in the second requirement.

A satisfactory solution of the problem has now been found in the use of the high-alloy non-magnetic cast irons. These irons contain sufficient alloys to render the structure of the metal austenitic. Some of the compositions giving this structure produce castings which have the desired combination of non-magnetic properties with high electrical resistance. In addition, special compositions have marked resistance to corrosion and heat.

Perhaps the best known of the non-magnetic cast irons is the high-nickel nickel-manganese austenitic cast iron known as "Nomag"* developed fifteen years ago by Mr. S. E. Dawson and Messrs. Ferranti, Limited. This firm supply large quantities of non-magnetic castings and we are indebted to them for the data accompanying this article.

"Nomag" has a magnetic permeability as low as 1.03, which means that for all practical purposes it is completely non-magnetic. This figure is given in the table below, in which "Nomag" is compared with other engineering materials. The table also gives comparative figures for specific resistance and temperature coefficient of resistance.

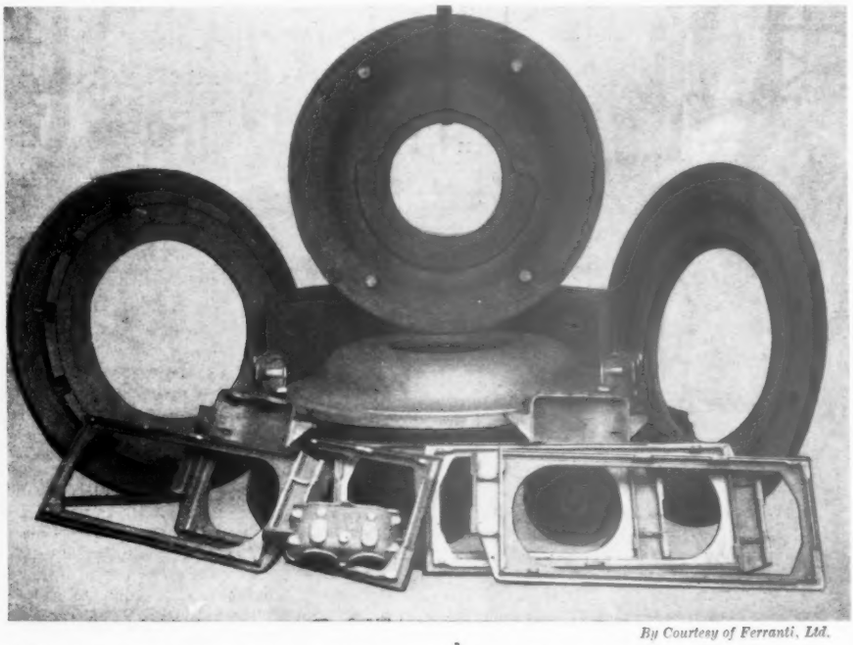
Material.	Magnetic permeability. Maximum.	Specific resistance, micro-ohms per cm. cube.	Resistance-temperature coefficient between 0 deg. C. and 100 deg. C. per degree C.
"Nomag" ..	1.03	150	0.00045
Cast iron	240.00	95	0.0019
Steel (Siemens-Martin)	8,350	18	0.003
Brass (annealed) ..	approx. 1	7.0	0.002
Pure copper (annealed)		1.59	0.00427
Pure aluminium ..		2.62	0.00423

"Nomag" is soft and easily machinable. Its tensile strength is similar to that of ordinary grey iron, but it is distinctly tougher and more resistant to shock. The lower electrical and magnetic losses render it particularly suitable for such castings as alternator end rings, cable and terminal boxes, covers and fittings for oil switches and transformers. As an example of the usefulness of the iron in these applications it may be mentioned that on test the temperature rise in a cast-iron ring through which was threaded a conductor carrying an alternating current of 1,000 amperes for 30 min. was 50 deg. C., whilst the "Nomag" ring under similar conditions gave a temperature rise of only 4 deg. C.

In metering equipment it is essential that electro-magnetic losses in the castings used for meter cases, etc., should be at a minimum, to ensure accuracy. Non-magnetic cast iron is thus ideal for these conditions.

The high electrical resistance of the austenitic

(*Concluded in next column.*)



By Courtesy of Ferranti, Ltd.

FIG. 1.—A FEW APPLICATIONS OF NON-MAGNETIC CAST IRON IN THE ELECTRICAL INDUSTRY.

* "Nomag" is a registered trade mark.

Correspondence

[*We accept no responsibility for the statements made or the opinions expressed by our correspondents.*]

The Earliest Grey-Iron Casting

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—I have read a printed letter from Mr. J. A. Rabbitt entitled "The Earliest Grey-Iron Casting" in your issue of April 4, 1935, p. 232. The foundry industry in Kawaguchi district, near Tokyo, is, Mr. Rabbitt states, an unparalleled feature throughout the world, I suppose. There are about ten thousand persons out of a total population of forty thousand engaged in foundry work. There about four hundred iron, four non-ferrous metals and one steel foundry are standing in a row.

Mr. Rabbitt stated that a Chinese master from South China taught foundry work in many parts of the country during Kamakura period (A.D. 1270). This is correct, but in this district the art of making castings was handed down by the descendants of a famous founder Temmei Kuniie, trained in the Tan-nan district of Kawachi in this country during the year of Horeki (A.D. 1410). Thus its art is not derived from China but from ancient Japan.

Yours, etc.,

R. MAEDA.

Metallurgical Department,
Faculty of Engineering,
Tokyo Imperial University,
Tokyo, Japan.

July 5, 1935.

Catalogue Received

Pig-Iron. A 32-page brochure received from the Barrow Hæmatite Steel Company, Limited, Barrow-in-Furness, Lancashire, breaks new ground in publicity for pig-iron. The compiler has taken for his text "Low-phosphorus content induces soundness in grey-iron castings," and he has drawn on the scientific investigations of West which were included in the First Report of the Work of the Cast Iron Sub-Committee of the Institute of British Foundrymen and numerous other researches, both British and foreign, for support. Then he has shown how the "SP" range of foundry pig-irons made by his concern "fill the bill" in this respect, as they run between 0.10 and 0.30 per cent. phosphorus. The range is divided into "standard" and high and low manganese, with diminishing silicon contents with increasing numbers. Once again we have to register a protest against the use of cream or anything other than white paper as a background for the reproduction of photomicrographs. The lay-out, the use of illustration, and the choice of type are all excellent. The technical data drawn upon is reliable, whilst its presentation has been sufficiently simplified that it will appeal to the more practically-minded foundryman. We strongly advise our readers to procure a copy for personal reference, as its study will help to crystallise the main factors in the production of sound castings.

(*Concluded from previous column.*)

irons combined with their toughness renders them particularly useful for electrical-resistance grids. The low resistance-temperature coefficient ensures minimum variation of resistance with fluctuating temperature, while the high resistance enables thicker and more open grids to be employed than in the case of ordinary cast iron. Finally, the heat resistance of the irons minimises distortion and scaling at high temperatures.—From "The Nickel Bulletin."

The Viscosity of Cupola Slags in Molten State*

By TATSUO MATSUKAWA

Introduction

In the operation of a cupola for the manufacture of iron castings, unless one uses some proper flux, a very viscous, sticky slag is produced. This is very difficult to handle; it prevents the smooth downward flow of materials and the even distribution of blast in the melting zone. The slag consists of the ash of the coke, which may amount to 10 per cent. or more of the weight of the coke charged, a part of the cupola lining which may be melted away during the progress of heat, sand and rust adhering to the scrap and pig-iron in the charge, and perhaps some iron, silicon and manganese oxidised in passing through the melting zone. The production of good-quality cast iron under such conditions is practically impossible. Some fluxes, in addition to limestone, such as dolomite, fluorspar, etc., have been used to give a good fluidity to the slag.

Dierker[1] says that smoother cupola operation may be secured by the use of dolomite as a flux instead of limestone, because magnesia lessens the viscosity of the slag more than lime does. But dolomite is not yet used currently in practical foundry operations, as limestone is cheaper. In regard to fluorspar, Deurvorst's[2] investigations led him to the following conclusion: from a critical review of the various factors involved, it is said that the partial substitution of fluorspar for limestone has no effect on the operation of cupolas, except that the lining is more rapidly attacked.

According to D. Saito,[3] the amount of limestone added as flux in practical cupola melting in Japan varies from 0.4 to 6 per cent. of the iron charge, according to the quality and quantity of coke used; but the range is too wide. This shows the lack of exact knowledge about the relation of the amount of limestone and the slag condition, *i.e.*, viscosity. The writer investigated this problem in order to give some hints to practical foundry workers.

Experiment with 1-Ton Cupola

In this investigation a 1-ton cupola furnace at the Kurimoto Foundry was used to obtain desired samples, slags and cast iron. The diameter of the furnace is 24 in., and it has a forehearth and 6 rectangular tuyeres, 7 in. by 2.5 in. in section. Upon the 330 lbs. coke beds, the calculated limestone and the mixture of 247 lbs. of pig-iron and 60 lbs. of scrap were charged in every experiment. The samples of slag and metal were taken from this first charge, because in the foundry it was impossible to continue melting with the same combination of materials and with an unsuitable amount of limestone. The analyses of coke, pig-iron and limestone are shown in Table I.

TABLE I.—*Analyses of Materials used* (1-*ton Cupola*).

Pig-iron ..	T.C.	3.40%	Si 3.08%	Mn 1.26%	S 0.023%	P 0.203%
Coke ..	Ash	9.72%	F.C. 88.00%	V.M. 1.11%	Moisture	0.30%
	S	0.83%	P 0.04%	—	—	—
Limestone	SiC_2	1.85%	Fe_2O_3 & Al_2O_3	0.085%	$CaCO_3$	96.78%
	$MgCO_3$	1.36%	S 0.052%	—	—	—

Results of Viscosity Measurement

The analyses of slags and the results of viscosity measurement are given in Table II and Fig. 1.

The first column indicates the ratio of amount of limestone added simultaneously to the pig-iron in percentages. Slag No. 0, which was obtained with no limestone addition, has a high silica content as an acid open-hearth slag, and its viscosity and melting temperature are both very high.

When the limestone addition increases by 2, 3 and 4 per cent., the viscosity and the melting temperature of the slags decrease, but as from slag No. 4 they increase with the amount of limestone added. Slag No. 4, which was produced with a 4 per cent. limestone addition, shows the minimum value in viscosity and melting temperature. This is probably due to the formation of some fusible eutectic.

TABLE II.—*Analyses of Cupola Slags* (1-*ton Cupola*) (*per cent.*).

Slag No.	Limestone added.	SiO_2.	FeO.	Fe_2O_3.	MnO.	Al_2O_3.	CaO.	MgO.	P.	S.
	Per cent.									
L—0 ..	0	58.12	7.34	1.84	4.91	18.56	7.38	1.84	0.396	0.069
L—2 ..	2	50.40	14.79	2.21	4.07	11.48	13.66	2.71	0.240	0.150
L—3 ..	3	44.88	13.41	3.48	3.97	10.00	20.72	3.88	0.669	0.151
L—4 ..	4	42.70	13.47	3.49	3.82	10.25	26.38	3.66	0.613	0.161
L—5 ..	5	40.51	13.03	3.04	3.90	10.52	29.21	3.23	0.608	0.124
L—6 ..	6	38.28	11.64	4.50	3.56	10.32	31.50	2.86	0.424	0.118

Properties of Cast Iron

The chemical analyses of the cast iron produced are given in Table III. Cast iron No. 0, which was produced with no limestone, has absorbed much sulphur, actually 0.115 per cent. Up to No. 4 the sulphur content decreases rapidly, but cast iron produced with 5 and 6 per cent. limestone shows little benefit. Cast iron No. 0 has a 3.54 per cent. carbon content, but the others contain about 3.3 per cent. This is probably due to the difference of slag conditions: the sticky viscous slag has not been able to protect the cast iron from the carburising action of coke.

TABLE III.—*Analyses of Cast Iron* (1-*ton Cupola*) (*per cent.*).

Metal No.	Limestone added.	C.	Si.	Mn.	P.	S.
	Per cent.					
0	0	3.54	1.76	0.87	0.237	0.115
2	2	3.26	1.72	0.96	0.174	0.091
3	3	3.28	1.78	1.03	0.168	0.057
4	4	3.32	1.58	1.16	0.204	0.031
5	5	3.28	1.78	1.06	0.199	0.027
6	6	3.29	1.79	1.01	0.197	0.029

Except for a slight increase or decrease in the silicon and phosphorus content, the effect of the basicity of the slag was not noticeable. The content of manganese from 0.87 per cent. to 1.05 per cent. as the limestone addition increases from 0 to 4 per cent., but decreases after increasing the limestone addition above 4 per cent. It may be supposed that the slag of good fluidity has protected the cast iron from oxidation by Bessemerisation.

Fig. 2 shows the average value of tensile tests obtained from three separate test-pieces. Cast iron No. 0 has the poorest value, but it increases up to No. 4, and then decreases a little in No. 5 and No. 6. No. 2 showed an exceptionally good result; this may be attributed to its low-carbon content, caused by an irregularity of the charge.

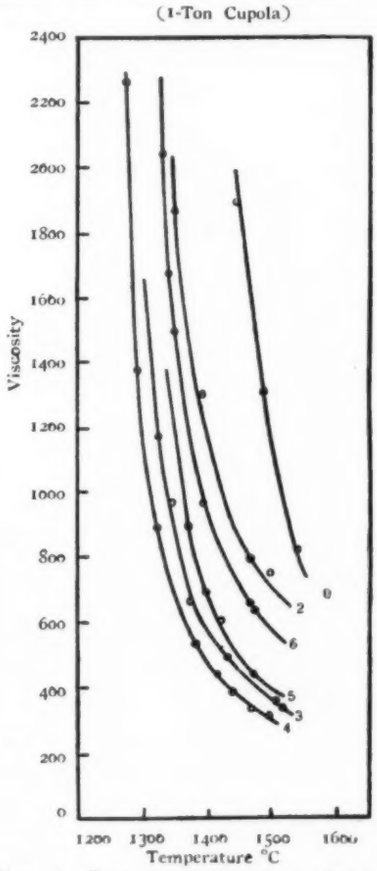


FIG. 1.—TEMPERATURE-VISCOSITY CURVES OF CUPOLA SLAG.

The temperature of molten cast iron from the cupola is about 1,450 deg. C. To produce cast iron of superior quality, the slag must have good fluidity at this temperature, because they contact continuously with each other in the furnace,

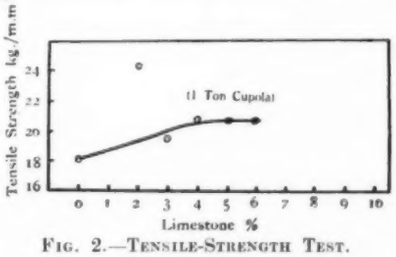


FIG. 2.—TENSILE-STRENGTH TEST.

avoiding the bad effect of glowing coke and oxidising atmosphere upon cast iron. Slags which satisfy the above demands are Nos. 3, 4 and 5 in this experiment. From the temperature-viscosity curves of slags, and the physical and chemical properties of cast iron produced, it may be concluded that the proper amount of limestone to be added as flux in this 1-ton cupola furnace melting is 3 to 5 per cent. of iron charge.

* Abstract of a Paper presented to the Autumn Meeting, 1933, of the Iron and Steel Institute of Japan.

1 FOUNDRY TRADE JOURNAL, 47 (1932), p. 372.

2 *Loc. cit.*

3 "J. Iron and Steel Institute," Japan, 12 (1929), p. 1097.

XUM

Waste-Wax Casting

METHOD OF GREAT ANTIQUITY

By E. A. SMITH, A.R.S.M.

The discovery that metals could be cast into definite shape by pouring them into moulds was a great step forward in their industrial applications. It was a discovery due in all probability to the close observation of an early metallurgist who noticed that the metal produced in his primitive smelting furnace flowed like melted fat or wax; and as it cooled received the impression of the surface on which it finally solidified. From such crude beginnings there was gradually developed the art of casting metals, particularly copper and bronze, which has been practised by almost all nations from very remote times.

The earliest castings, in simple sand impressions, consisted chiefly of weapons of defence and implements of the chase: but in course of time the art was extended to the production of objects of more artistic merit for personal adornment, and for domestic or ceremonial uses. The earliest practice of art metal casting dates from prehistoric times; and it is impossible to say with any degree of certainty how or where it originated, or to give to any individual or nation the credit of its invention.

As the result, however, of modern archæological research and discovery it has become increasingly evident that the art was practised in Asia at a very remote period; and that it most probably originated somewhere in the western part of that vast continent where archæological investigations are only just beginning to be made on a scientific basis. Gowland, the late authority on the metals in antiquity, has pointed out that certain bronze figures from Chaldea are attributed to a period not later than 2000 B.C., and although of very archaic form and rude execution, indicate that the casting of bronze must have been followed in that country even for many centuries before that remote date. Also if we accept the date 2205 B.C. given in Chinese annals for the casting of the nine bronze tripod cauldrons, often mentioned in historical records, then methods of casting must have been developed and used as early as 3000 B.C. or even earlier.

Casting in moulds of sand or loam is of very early date. Moulds of clay were probably introduced by the Chinese, and Gowland considers that it is almost certain that contemporaneous with their adoption the method of *cire perdu* casting was first practised. This somewhat unique method, commonly known as the waste-wax, or lost-wax method (From Fr. *cire*, wax, and *perdu*, wasted or lost), has been applied from very early times to artistic metal casting and forms an important link with the past history of foundry practice. It is a very simple method of producing a mould for the shaping of metal, and has been described many times, but it may be well to recall its salient features.

In the first place the object is very carefully modelled in wax. This model is then covered with a moderately thick coating of refractory clay which when hard forms a one-piece mould around the wax model. After drying out the moisture, the clay is heated or baked at a red heat to melt the wax which flows out through a channel made in the clay for the purpose. Thus the wax is wasted or lost, hence the name applied to the method.

The molten metal is then poured into the mould and completely fills the space vacated by the wax, producing in metal in every detail a reproduction of the original wax model. After being allowed to cool the refractory mould is broken away revealing the cast object.

The earliest known examples of *cire perdu* casting are solid, and are small, as solid casting, even by this process was evidently considered too wasteful where work of any size had to be carried out, especially in gold or silver. Later—probably with a view to economising metal—hollow castings were made by the *cire perdu* method by the use of a core as described later. A number of ancient Egyptian castings of copper and bronze of undoubted antiquity examined by Garland and Bannister show that they were made by the *cire perdu* method as early as 3000 B.C. Petrie also states that the casting of bronze in ancient Egypt was generally done by this method. It was also used at a very early date by the Egyptian goldsmiths for casting small objects in both gold and silver, and many beautiful examples of their work are to be found in the British and other Museums. In later periods this method became very usual in Egypt.

The intrinsic interest in this method, however, is enhanced by the remarkable discovery in recent years by Sir Leonard Woolley of certain castings in gold, silver, and copper, at that ancient city Ur of the Chaldees in Southern Mesopotamia of which we have heard and read much of late. These fine examples of the goldsmiths and jewellers of 3500 B.C. and more years ago were without doubt cast by the waste-wax method, and are therefore of special interest to the craftsman, as they are the oldest examples of this method of casting extant.

Ancient Craftsmanship

In describing these discoveries, Dr. Woolley states that everything in the cemetery where the objects were found points to a civilisation old and settled. Their knowledge of metal working was considerable, and in fabricating gold, silver and copper they exhibited a skill in design and a technique in execution such as few ages have surpassed. The craftsmanship which produced those treasures went back to an extraordinary early period.

Shaping metals by the skilful hammering of sheet doubtless preceded by many centuries, perhaps by tens of centuries, the artistic casting of metals, but the invention of the *cire perdu* method did much to extend the use of metals for artistic purposes, as it enabled the craftsman to obtain the requisite shape and nicety of detail in objects that could not well be fashioned in sheet metal. It also permits of much finer impressions of the model being taken than can be obtained with the ordinary sand mould.

Although a date of some 3,500 years before the Christian era is assigned to the cast objects found at Ur, the delicacy and skill displayed in their production indicates a degree of metallurgical knowledge and technical skill possessed by the artificers of that time that could only have been attained long after the method was first known, and represents without doubt the accumulated experience of many generations of founders. Hence it would not be unreasonable to conclude that the *cire perdu* method was in use some 4000 or even 5000 B.C.

As an instance of solid casting in gold, we have the magnificent little monkey from the grave of King Mes-Kalam-dug, ruler of Ur, more than 5,000 years ago, and made by some craftsman of Ur. It is a very fine piece of miniature work, little more than half an inch in height, and is seated on a slender copper rod, which is probably the shaft of a pin.

Another beautiful casting is the donkey of gold (electrum), which forms the mascot on the silver rein-ring from Queen Shub-Ad's sledge chariot. This is a skilful piece of casting perfectly true to nature in every detail. In addition to these two outstanding examples of waste-wax casting, there are quite a number of small gold ornaments in the form of animals, chiefly stags and bulls, which formed part of the Queen's ceremonial crown, and were all in a good state of preservation.

"The final traces of the people who lived at Ur are lost about 800 B.C., but the Babylonians inherited their art, and the Assyrians took it over, too. The Phœnicians, technically brilliant but with no invention, also adopted it, and spread it around the Mediterranean, until it became familiar to the Greeks and helped to form the great Grecian art." (Woolley.)

The *cire perdu* method was not introduced into Greece—the country to which we owe the most perfect antique examples of it—until about 600 B.C. Its revival was largely due to the activities of the celebrated goldsmith Benvenuto Cellini, who constantly employed it and improved the technique of the method.

A later development of the *cire perdu* method was the casting of hollow objects with the aid of a core. The procedure for cored work was to make a core of some loam material, which was formed roughly to the shape of the object to be made, and then coated with a thin layer of wax. On this wax coating the craftsman carefully modelled the object. The mould itself was then completed in the usual way by covering the wax with clay, but some means was required for preventing any movement of the core after the wax was finally melted out. For many years the method of fixing the cores in ancient work remained a mystery, but investigations by Garland and Bannister on ancient Egyptian core castings of copper and bronze leave little doubt that struts of iron wire, sometimes very thin, were used as supports. Owing, however, to the ready oxidisability of iron, the struts had very frequently corroded away and completely disappeared. But in some few cases remains of the struts had been found after very careful examination, and thus confirming the method of fixing the cores.

The importance of the accurate adjustment of the cores is evident when it is stated on the authority of Sir Flinders Petrie that in ancient Egyptian bronze castings made by the *cire perdu* method "the metal was often run as thin as 1/50th of an inch, so that a shift of the core by as little as 1/100th of the inch would throw the casting out, and make a flaw." In later time it is known that iron cross supports passing from the core through the wax to the mould were used, and this method continues in use in Egypt and elsewhere at the present time.

The *cire perdu* method gives a perfect reproduction of the finest details of the original model, consequently little, if any, work was left for the engraver to do on the casting itself.

From the foregoing details it is evident that the waste-wax method is of very ancient origin and is the earliest known method of art casting; it was known to the Sumerians and to the goldsmiths of Ur most probably some 5000 years B.C. It was more fully advanced by Greek casters several centuries before the Christian era. But whilst it was actively developed in many parts of Europe, the method does not appear to have received very serious attention in this country until the latter part of the nineteenth century, when it began to be applied to art bronze casting. From that time to the present day the interest in the method has gone on increasing: and there is now no difficulty in getting bronzes cast by the waste wax method in England, and large castings are constantly being made.

The latest development is its application to the casting of aluminium, in which metal some statues of considerable size have recently been made in America and elsewhere.

Mr. T. Teisen, C.E., of Birmingham, has received an order for a small oil-fired glass-melting tank furnace of new design from Butterworth Bros., Limited, Newton Heath Glass Works, Manchester. The complete erection of the furnace will be under the supervision of Mr. Teisen's furnace builder or engineer, and the tank will be used for founding at specially-high temperatures.

XUM

Some Notes on Ingot Moulds*

By T. SWINDEN, D.Met., and G. R. BOLSOVER, F.Inst.P.

Mould Costs

By far the greatest proportion of the world's steel production is cast in the form of ingots for subsequent manipulation by rolling or forging. A very rough estimate indicates that the annual consumption of ingot moulds is of the order of 100,000 tons. Practically the whole of this is in the form of cast iron, and therefore the subject is of considerable interest to the ironfoundry industry. At the same time, it is necessary to keep in mind that the ingot mould is merely a tool required to give the desired shape to the steel ingot, and its value is to be considered under two headings: (*a*) the cost per ton of steel produced, and (*b*) the influence of factors connected with the mould on the quality of the resulting ingot.

As regards the cost per ton of ingots, in a recent Paper by Mr. J. Blakiston, before the Middlesbrough Branch of this Institute, it was stated that the value of castings of all kinds used in the ultimate production of a ton of semi-finished steel was approximately 10s. per ton, and that the ingot moulds, bottoms and slag ladles accounted for from 2s. to 5s. per ton.

Confining attention to ingot moulds, F. W. Morawa ("Stahl und Eisen," 51 (1931), Vols. 40 and 41, pp. 1221-28 and 1256-63) stated that the cost of moulds represented only some 3 per cent. of the cost of conversion in the steelmaking shop, which conversion cost represented about one-fifth of the total cost of the ingot. In the authors' opinion these values are very approximately correct. The ingot mould costs in the plants of the United Steel Companies, Limited, varied in 1934 from 9d. to 1s. 7d. per ton, according to the type of plant and steel being produced. The cost of bottoms varied from 1½d. to 4½d. per ton.

As a further approximate guide on this subject, if it is assumed, say, for rolling ingots that the weight of the mould is similar to that of the ingot produced and present prices for ingot moulds and mould scrap are accepted, then it can be estimated that if the mould gives a life of 40 casts, the cost per ton of ingot will be about 1s. 6d. per ton. If the life be 80 casts, the cost will be 9d. per ton, if 100 casts 7.2d. and if 200 casts 3.6d. These figures are not strictly accurate because other costs are involved if moulds give a short life, but it is sufficient to indicate that if, for example, the life of an ingot mould can be increased from 100 to 200 casts, other things remaining equal, this represents a possible economy to the steelmaker of the order of 3½d. to 4d. per ton.

It is necessary to recognise, therefore, that the possible improvements that can be made have a limitation in the value of the possible savings, and, as will be referred to later, the influence on the quality of the steel ingot produced is of greater importance than the saving to be achieved by increasing the life of the mould. At the same time it should also be noted that, taking an approximate figure of 7,000,000 tons of ingots produced annually in this country, an economy of 1d. per ton represents nearly £30,000 per annum.

Sufficient has been said perhaps to establish some idea of the value of this service to the steelmaker so far as the life of the ingot mould is concerned.

Mould Lives

The first essential in assessing the value of ingot moulds is to have an accurate system of recording data. In works of the United Steel Companies, Limited, it has been the custom for several years to keep a complete record of the life of every mould so that the results can be analysed by "maker," "size," "type," "composition," etc., and as regards the moulds which are made within the organisation, additional data as to iron mixture, cupola practice, casting temperature, analysis, etc., are tabulated.

Each month is recorded the life of every mould scrapped during that period, the cumulative average for the period is reported and also the average for the preceding half year. In Table I are given the six monthly average figures for a selected number of mould types at the various branches. The description will probably be sufficient to indicate to those interested the type of mould referred to, but if required the authors will be happy to provide actual sketches of each of the moulds in question. An analysis of these figures produces some interesting observations. It is seen that over a period of time in some shops the lives vary to a considerable extent, although it may be said, speaking generally, that there has been a general trend towards

DR. T. SWINDEN.

improvement; in some cases this has been quite marked. There are cases where one make of mould during a certain period has given consistently low results, while another make of similar mould has given much better results. This definitely indicates that the quality of the mould is primarily responsible. On the other hand, it will be noted that in certain periods there has been a tendency for all makes of moulds to give lives lower than average, and the general explanation in such cases is to be found in a change in shop conditions necessitating using the moulds with greater frequency. The authors have carried out specific experiments on this point and the indications have been that conditions which reduce the temperature to which the moulds are heated have a definite tendency to improve their life.

It is not proposed to enter into a closer analysis of these figures at the moment, but it is suggested that they will provide a useful basis for discussion and a valuable record in that they do represent carefully-recorded figures in a series of six melting shops operating under different sets of conditions. For the benefit of those who may not be conversant with the various plants, it may be stated that the Frodingham and Appleby branches are engaged primarily in the production of mild basic structural steels. The figures for the Templeborough branch relate essentially to mild basic steel but with a proportion of high-carbon steel. The ingots at the Rotherham branch are of acid steels of high-carbon and alloy quality. The Workington branch make acid-Bessemer steel of various types, while the values from the Fox branch relate to acid and basic open-hearth steel, mainly of alloy and special qualities. No values for electric steel are included in these figures.

It is at once recognised that such figures must depend to some extent on the type of steel being made and also to a considerable extent on the way in which the moulds are used. As regards the influence of the type of steel, it is known that mild steel and particularly free-cutting steel is more severe on the mould than higher-carbon steels, but, on the other hand, it is essential that the mould should be in first-class condition when casting expensive alloy steels, and a mould would be discarded from a shop making such steels at an earlier point than would be the case in a shop making, say, mild structural steel.

The value of a good mould in producing better-quality ingots is far greater than the intrinsic value of increasing the number of lives within the range that at present appears possible.

Influence of Mould Metal on Mould Life

One ought perhaps to state first personal ideas concerning the mechanism of breakdown and type of failure which ultimately determines the life of the mould, but it has been decided instead to present some data concerning the influence of composition and deal with these other items later.

The authors propose to confine their attention meantime to iron moulds, and it is the fact that at least in many works hematite iron has been specified, having in mind the higher salvage value of the used moulds. Nevertheless, it has been suggested that a fairly pure hematite was a good choice apart from this, on account of its high resistance to thermal shock. It is not necessary, at a meeting of foundrymen, to outline the influence of the various elements normally found in hematite iron and describe the effect of the various elements on the structure and properties of the material. The authors have found —and this experience is, it is thought, in full accord with that of many other observers—that the composition can vary within fairly wide limits without any consistent effect on the mould life. In other words, moulds having abnormally good and abnormally bad lives are found to differ only very slightly in chemical composition. Far more importance is no doubt to be placed on the structure of the material, with particular reference to the form and distribution of the graphite carbon.

The authors have noted with interest the recent work of the Cast Iron Research Association in this direction, and look forward with great interest to the result of practical tests on the special type of iron which now promises to become available, having a high total carbon, a considerable proportion of which may be graphitic, but in a very fine and evenly-dispersed form throughout the structure.

Uniformity of structure is no doubt also a very important matter, having in mind that a large proportion of moulds fail by cracking long before the surface is sufficiently deteriorated to warrant the mould being discarded.

A general statement of the analysis of the moulds that have been used by this company would be as follows:—Total carbon, 3.5 to 3.75; combined carbon, 0.3 to 0.6; manganese, 0.6 to 1.0; silicon, 1.9 to 2.3; sulphur, 0.03 to 0.05; and phosphorus, 0.03 to 0.045 per cent. There is a tendency at the present time to work towards a rather lower silicon, say 1.7 to 1.9 per cent., with manganese higher at 0.9 to 1.1 per cent. It is also a matter of uncertainty whether the low phosphorus previously specified is best from the point of view of mould life, some evidence being provided that a rather higher phosphorus, say 0.06 to 0.08 per cent., is to be preferred. In this direction it will be noted that some German moulds contained phosphorus in the region of 0.2 per cent.

* A Paper read before the Annual Meeting of the Institute of British Foundrymen at Sheffield.

XUM

Alloyed Cast-Iron Ingot Moulds

It is interesting to note that none of the special heat-resisting qualities of cast iron has fulfilled the early expectations that they might provide super-quality ingot moulds. There are still differences of opinion as to whether some of the low-alloyed iron moulds are worth while. Personal experience so far has been rather mixed, but, on the whole, the authors would say that they have no evidence to show that the addition of chromium or nickel is worth while. In one series of tests the addition of 0.5 per cent. chromium at Stocksbridge showed a definite improvement on 13 moulds, the average life being 63, as against an average of similar moulds without chromium of 45. A further set of moulds, having additions respectively of 0.25, 0.5 and 1.25 per cent. chromium, did not confirm the earlier results. Batches of experimental moulds containing 0.5 per cent. chromium were used at Templeborough and at Frodingham. The final reports were that there was no improvement in the life of the moulds.

Experimental batches of moulds containing 1.0 per cent. nickel showed no advantage; in fact, the results were inferior to those of the standard composition. There is, however, some indication that somewhat higher manganese would be advantageous, and moulds containing 1¾ per cent. manganese are under test at the present time.

The authors have examined the influence of the admixture of steel scrap, and also the influence of the proportion of scrap mould metal used. No advantage was gained by the admixture of steel scrap except in so far as this may be used to regulate the content of silicon. A careful series of tests on the use of mould metal indicates that under one condition of manufacture the best results were obtained with an admixture of 30 per cent. of mould metal.

TABLE I.—*Six Monthly Average Lives of Ingot Moulds at the Various Works of the United Steel Companies, Ltd.*

Type of mould.	Branch.	Maker.	To Dec., 1934.	To June, 1934.	To Dec., 1933.	To June, 1933.	To Dec., 1932.	To June, 1932.	To Dec., 1931.	To June, 1931.
70-cwt. Tapered top	Frodingham	D	105	97	126	134	128	116	122	—
,, ,, ,,	,,	E	—	79	92	110	126	113	—	—
,, ,, ,,	,,	F	100	88	118	98	101	92	90	—
,, ,, ,,	,,	G	89	80	97	125	115	89	81	—
,, ,, ,,	,,	C	93	80	104	106	105	—	—	—
80-cwt. Tapered top	,,	G	93	—	—	—	—	—	—	—
,, ,, ,,	,,	C	51	49	73	65	—	—	—	—
70-cwt. Brick top ..	,,	D	98	99	28	—	—	—	55	—
6-ton ,, ,, ..	Appleby	G	45	31	17	11	—	—	—	—
6-ton Long tapered top	,,	C	83	62	—	26	—	—	—	—
6-ton Long tapered top	,,	G	—	—	39	32	35	41	40	25
6-ton Long closed top	,,	G	72	79	39	—	—	—	—	38
6-ton Long closed top	,,	E	83	70	32	—	—	—	—	41
10-ton Long closed top	,,	D	84	71	20	—	—	—	—	—
10-ton Long closed top	,,	E	65	58	42	—	—	—	—	38
10-ton Long closed top	,,	G	82	67	—	—	—	—	—	—
10-ton Brick top ..	,,	D	53	37	—	—	—	—	—	—
,, ,, ,, ..	,,	E	28	42	30	30	—	—	16	—
15-ton Rammed top	,,	G	62	54	56	47	43	46	49	41
21-in. S.C.T.	Templeborough	B	83.22	87.23	72.75	74.30	76.42	85.8	85.4	82.4
,, ,, ...	,,	G	76.77	77.61	82.69	81.03	80.90	89.7	96.0	79.0
,, ,, ...	,,	F	99.00	97.93	86.59	92.82	84.56	—	—	70.5
,, ,, ...	,,	H	79.00	90.27	79.68	76.05	—	—	—	—
,, ,, ...	,,	C	77.57	78.02	—	—	—	86.0	95.0	78.0
11-in. Octagon ..	Rotherham	B	52.66	33.33	50.00	53.0	30.4	29.29	42.5	43.6
17-in. sq. Centre run	,,	B	41.89	45.85	42.63	43.88	38.8	40.3	45.33	46.4
18 × 19-in. Closed bottom	,,	B	68.43	57.54	59.50	48.0	47.0	36.2	53.25	53.1
14 × 12-in. Sided open ended ..	,,	B	41.40	34.43	46.70	49.48	30.12	—	—	—
19 × 12-in. Sided open ended ..	,,	B	46.51	56.56	47.92	45.20	19.0	—	—	—
19½ in. Sq.	Workington	C	—	54.23	43.63	54.27	45.5	—	—	—
21 × 19¼ in.	,,	C	—	64.84	58.15	55.23	—	—	—	—
26-cwt. Plug	Stocksbridge	A	40	37	33	32	30	37	35	13
38-cwt. Plug and recess (long) ..	,,	A	47	41	43	48	59	53	—	—
38-cwt. Plug and recess (short) ..	,,	H	38	39	—	—	—	—	—	—
38-cwt. Recessed ..	,,	F	—	39	40	—	30	19	—	20
45-cwt. Plug	,,	F	29	30	29	—	—	—	—	19

Where no figures are inserted, either these particular moulds were not in regular use at the time, or the records are incomplete.

Extensive trials have also been made comparing cupola-melted iron with a mixture of mixer metal and refined iron. The latter proved to be somewhat superior, but moulds made from all refined iron were no better than the standard cupola iron. The use of molybdenum has been advocated, but no convincing results are yet available. The same applies to certain other special alloys which naturally arise in one's mind.

The above comments are necessarily somewhat brief and sketchy, but they do tend to indicate what is felt to be the right line of progress, namely, that a most satisfactory and economical mould will be one which does not depend essentially on the addition of expensive special alloys, but on obtaining the correct structure in a suitable hematite iron. The subject has, of course, been referred to by many other writers, but it is not proposed to give a lengthy statement of other published data. The subject is having the attention of the Heterogeneity of Steel Ingots Committee, and has been referred to in several of their reports. Morawa (*loc. cit.*) makes a useful contribution to this subject, and Table II is reproduced from this Paper. In the recent Paper by Blakiston (*loc. cit.*) one is again told that, after the careful observation of over 250 moulds, it was found that the analysis, within reasonable limitations, had no influence on the subsequent life of the mould. Moulds of identical analysis gave 13 and 120 lives respectively. He suggests that the most suitable analysis is:—Total carbon, 3.50 min.; combined carbon, 0.50 max.; silicon, 1.80; manganese, 1.20 max.; sulphur, 0.03 max.; and phosphorus, 0.06 per cent. max. He makes an interesting statement that the best results are obtained by blending equal proportions of two different makes of hematite, one high and one low in silicon, together with small additions up to 6 per cent. of steel scrap.

The editorial in THE FOUNDRY TRADE JOURNAL, Volume 52, February 28, 1935, also draws attention to an interesting statement by Mr. J. Léonard, President of the Belgium Foundrymen's Association. Firstly, that different types of moulds fail in different ways, concerning which it is hoped to say something later, and gave as his opinion that, as regards composition, the total carbon should be 3.5 per cent., manganese 0.4 to 0.5 per cent., with 1.7 per cent. of silicon, while further Continental research workers have standardised on 3.75 per cent. carbon and 1.2 per cent. silicon. Mr. Léonard also attaches considerable importance to grain size.

Mr. Blakiston refers to the much longer lives obtained on the Continent, mentioning figures for 4-ton moulds up to 400 casts. Morawa appears to regard 250 casts as a normal life. This matter has naturally had the authors' close attention. They believe, on the one hand, that in Continental practice, where such lives are obtained, moulds are continued to be used far beyond the point at which they would be scrapped in this country on account of the influence on the quality of the surface of the resulting ingot, but, nevertheless, there is good reason to believe that both from the point of view of the quality of the mould and the care taken in its use, Continental practice on the whole is somewhat ahead of the average practice

TABLE II.—*Analyses of Cast-Iron Ingot Moulds.*

	Legrand. Per cent.	Shiokawa. Per cent.	Hruska. 1. Per cent.	Hruska. 2. Per cent.	Works A. Per cent.	Saar Works. Per cent.	Witkowitz. Per cent.
T.C. ..	3.25–4.95 as desired.	2.5–3.5	2.5–3.5	2.5–3.0	3.4–3.9	4.0–4.6	3.9
Gr. ..	80 per cent. of the T.C.	70 per cent. of the T.C.	Not given	Not given	70–80	80–88	3.1
Si ..	70 per cent. of the T.C.	1.0–2.0	1.0–1.5	1.0	2.0–3.0	1.9–2.2 not under 1.8	2.2
Mn ..	0.5–0.8	0.5–1.8	0.75–1.20	1.0–1.8	0.5–1.2	0.45	0.59
P ..	max. 0.100	under 0.2	under 0.15	under 0.15	0.08–0.12	under 0.10	0.19
S.. ..	max. 0.050	under 0.06	under 0.06	under 0.06	0.01–0.03	0.06–0.07 0.05–0.06 preferably under 0.04 since Cu high	0.039
Cu ..	—	max. 0.2	—	—	—	—	0.11
Cr ..	—	0.05–0.50	—	0.25–0.50	under 0.20	—	—

Legrand.—"Fond. mod." 20 (1926), S. 181/88. Shiokawa.—"Stahl und Eisen," 43 (1923), p. 1140. Hruska.—"Iron Age," 123 (1929), pp. 539/41.

in this country. Some years ago, the authors obtained some moulds from Germany, and the results may be of interest. One batch obtained in 1930 had the following average composition: —Total carbon, 4.0; combined carbon, 0.6; silicon, 0.65; manganese, 1.15; sulphur, 0.014; and phosphorus, 0.23 per cent. These were not of a type on which strictly comparable results with existing types were obtainable, and therefore a further set of six moulds was obtained on the standard 21-in. S.C.T. type in common use in the Templeborough plant. A complete analysis of each of the six moulds is given in Table III,

TABLE III.—*Composition and Life of German Moulds.*

Mould No.	T.C.	C.C.	Si.	S.	P.	Mn.	Ni.	Cr.
1	3.82	0.55	0.86	0.060	0.166	0.75	0.04	0.10
2	3.83	0.60	0.85	0.067	0.162	0.60	0.03	0.08
3	3.77	0.44	0.91	0.060	0.165	0.63	0.04	0.07
4	—	—	0.99	0.070	0.186	0.56	0.02	0.04
5	3.72	0.57	0.91	0.064	0.177	0.58	0.05	0.06
6	3.70	0.57	0.86	0.053	0.180	0.54	0.04	0.07

No.	Life.	Type of Failure.
1	137	Cracked slightly after 132; kept in use until not safe to use further.
2	159	Cracked-up corner of mould.
3	102	Cracked-up corner of mould.
4	138	Cracked-up corner of mould.
5	127	Cracked-up corner of mould after 102 casts; kept in use until not safe to use further.
6	116	Cracked after 72 casts; kept in use until not safe to use further.

together with the lives obtained and the type of failure. Attention is directed to the comparatively low silicon and the high phosphorus.

The average life of six moulds was 129.6 casts, with a consumption of 16.4 lbs. of mould metal per ton of steel made. It was reported that the moulds were particularly tough to break up compared with standard moulds.

The microstructure showed a fairly even distribution of graphite in definitely finer formation than that of a standard mould. At the time of this trial, the average life of domestic standard mould was 95 and the company was advised that the German mould was giving a life of 200 casts in Germany. It could therefore be calculated that, had the values of the moulds and resulting scrap been similar, the German mould would show an advantage of 2.06d. per ton if used in accordance with English practice and an

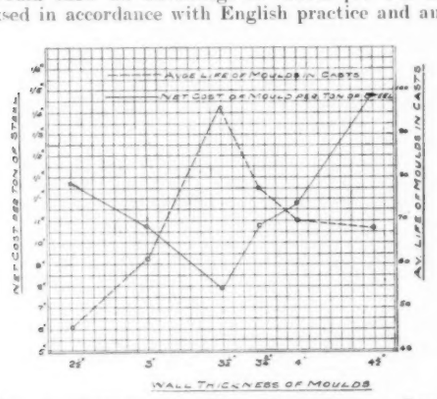


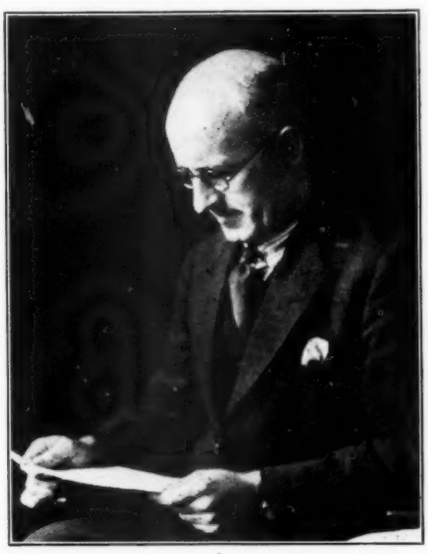
FIG. 1.—INFLUENCE OF WALL THICKNESS ON LIFE OF AND COST OF INGOT MOULDS USING 21-IN. S.C.T. INGOT MOULDS AT TEMPLEBOROUGH.

additional 1.96 per ton if used in accordance with German practice and a total of 200 lives obtained. In point of fact, of course, the German moulds were much more expensive and the value of the resulting scrap was lower. It did, however, establish these two points, namely, that the mould material of these German moulds was superior to domestic, and secondly, that if the figures are accepted, German practice is capable of prolonging the life of the moulds to the extent stated, with the proviso that the quality of the ingot produced towards the end of the life would probably be unacceptable for many of the classes of steel and standard of inspection to which the steelmakers are called upon to work in this country.

Influence of Design

It is not within the scope of this Paper to enter into a detailed statement on this particular subject. Many important Papers have been read and several bibliographies are available to those interested. Quite properly, most of these Papers have had reference to the influence of mould design on the characteristics of the resulting ingot, because, as has before been stated, the saving of one or two per cent. in the yield of satisfactory steel is of far greater importance than extending the mould life. At the same time, a careful study of the way in which moulds fail, indicates that some assistance can be given in design, quite apart from improving the quality of the mould metal.

It is also at once clear that the design of mould should have particular reference to the type of



MR. G. R. BOLSOVER.

steel being made in that the mould which is most satisfactory and economical in the one case is definitely not so in the other, when one considers the wide range of steels produced, ranging from the perfectly solid alloy-steel ingot with considerable taper (probably corrugated sided) and equipped with feeder head; the larger ingots employed for semi-killed steel for structural purposes; and the mould specially designed for the most economical production of rimming steel. The factors of ratio of length to diameter, taper, shape of sides (*i.e.*, flat, convex, concave or corrugated), corner radius, thickened bottoms, etc., all require to have careful consideration.

Having standardised the type of mould, it is possible to work out more accurately the influence of one or other variable on the economic value. One such set of experiments is given relative to the influence of wall thickness.

Having standardised the 21-in. S.C.T. mould at Templeborough, a series of moulds were made having a wall thickness respectively of 2½ in., 3 in., 3½ in., 3¾ in., 4 in. and 4½ in. Six moulds of each thickness were made and used under as nearly similar conditions as possible. The results fell on to a perfectly definite curve and the results are shown in Fig. 1, indicating quite definitely that 3½-in. wall thickness was the most economical for this type of mould. This is quoted merely as an example, and it is readily possible for any user to ascertain for himself similar data for other types of moulds. It may be added that this has since been checked on other extensive series within the region 3 in., 3½ in. and 4 in. for the mould in question and the desirable thickness of 3½ in. confirmed, and that in these tests such items as the complete analysis of every mould, foundry casting temperature and conditions of use have been most carefully controlled to ensure that the comparison was valid.

The life of the mould will obviously be appreciably affected according as to whether the mould is used for running direct or casting the ingots through a centre bottom runner. The latter system is kinder to the mould, avoiding risk of cutting by the metal stream due to contact with either mould wall or bottom, but the system adopted must be decided by the effect on the steel produced rather than mould life. Another factor is the use of separate mould bottoms with open-ended moulds which gives a definite improvement in mould life, whether casting uphill or direct.

It is again insisted that the ingot mould is merely a means to an end, and the first important decision to be made in any melting shop is the most suitable shape, size and weight of ingot to give the maximum production of sound steel, together with the most advantageous method of manipulation. It is clearly important to decide in a mass-production plant whether the standard ingot shall be 2½ tons, 3 tons, 4 tons, etc., and this requires to be decided alongside the capacity of the mills before the finer points of mould design can be settled.

(To be continued.)

Suggestions for Research on Steel Castings

In a written contribution to the discussion on the Paper presented to the Sheffield Conference of the Institute of British Foundrymen by Prof. J. H. Andrew, D.Sc., DR. W. H. HATFIELD, F.R.S. (Sheffield), wrote that he entirely agreed with Professor Andrew that the greatest trouble in castings was in respect to blowholes and contraction cavities. As regards the systematising of the method of feeding, whilst he agreed that this was most desirable, the types of casting were so varied that it would be difficult to lay down any simple set of rules and the various foundries each had their own methods of procedure according to their individual experience. Work, however, was being done by the Steel Castings Research Committee on this point.

The writer agreed that an extensive research on the influence of added elements on contraction would be most valuable, but pointed out that this would not eliminate the large solid contraction which, owing to the different rates of cooling throughout the mass, was at least of equal importance.

As regards facing sands, the requirements varied according to the form of castings being made, and from this point of view a foundry working on repetition work, producing large quantities of castings to a particular pattern, had a great advantage. At the same time, a foundry producing castings of miscellaneous types had greater facilities for studying the response of different mixtures to the varying factors.

He was afraid that Professor Andrew was somewhat optimistic in his view that forged material might be generally replaced by heat-treated castings.

With regard to alloy steel castings, the writer did not consider that the fact that the critical point was below 460 degrees C. was any guarantee of safe heat-treatment. Such alloys were most probably air-hardening and high internal stresses had to be met during and after cooling.

As regards details of practice, such as the atmosphere of the melting furnace, casting temperatures, and fluidity, he agreed that these were of great importance but, whilst it should be recognised that it was desirable to have full knowledge of these influences, and to regularise practice where possible, there was a limit to the extent to which this could be applied in foundry work.

XUM

Brussels International Foundry Conference

SEPTEMBER 20 TO 29

As previously announced, an international foundry congress will be held in Brussels from September 20 to 29 at the Brussels Exhibition. It is organised by the Belgian Foundrymen's Association under the auspices of the Foundrymen's International Technical Committee. The following is the provisional programme:—

Friday, September 20.

9 to 10.30 a.m.—Registration of participants.

10.30 a.m.—Official opening of the Congress under the chairmanship of the Minister of Economic Affairs; address of welcome by the President of the General Committee; reply by the President of the Foundrymen's International Technical Committee (Mr. Gierdziejewski, of Poland).

12.30 p.m.—Luncheon at the Exhibition.

2.30 p.m.—Technical session.

6 p.m.—Meeting of the International Committee. Evening free.

Saturday, September 21.

9 a.m.—Works visits.

1 p.m.—Luncheon at the Exhibition.

2.30 p.m.—Technical session designed to interest foremen and charge hands.

Later.—Reception by the civic authorities at the City Hall.

Sunday, September 22.

10 a.m.—Technical session designed to interest foremen (a special organisation has been created for the reception of this grade of participant).

1 p.m.—Luncheon for the specific purpose of meeting with the foremen and chargehands.

3 p.m.—Visit to the "Alberteum" Palace of Science. Afternoon free.

Monday, September 23.

9 a.m.—Visit to Bruges.

Tuesday, September 24.

9 a.m.—Works visits.

1 a.m.—Luncheon at the Exhibition.

2.30 p.m.—Technical session.

4.30 p.m.—Meeting of the International Committee for the Testing of Cast Iron.

6.30 p.m.—Reception at the Exhibition by the Committee of "Old Brussels."

Wednesday, September 25.

9 a.m.—Technical session.

1 p.m.—Luncheon at the Exhibition.

3 p.m.—Works visits.

8.30 p.m.—Closing banquet under the presidency of the Minister for Economic Affairs.

September 26 to 28.

Excursion to the Valley of the Meuse and the Belgian Ardennes, passing through Waterloo, Namur, Dinant, the Han Grottos, Château d'Ardenne, Spa and Liége. At Liége there will be more works visits and a "Goodbye dinner" is to be given to the foreign visitors.

PAPERS

The following Papers have been promised:—

(1) "Machinability," by H. H. Beeney. (British Exchange Paper.)

(2) "Special White Irons," by M. Balay and — Chavy. (French Exchange Paper.)

(3) "The Soundness of Steel Castings," by M. J. Obrebski. (Polish Exchange Paper.)

(4) "Researches on Artificial Core Oils," by A. Swagerman. (Dutch Exchange Paper.)

(5) "The Commercial and Technical Potentialities of Malleable Cast Iron," by H. A. Schwartz. (American Exchange Paper.)

(6) "Proposals for the establishment of an International Understanding for the Control of Moulding Sands," by Prof. Dr. Aulich. (German Exchange Paper.)

(7) "The Influence of Titanium on Primary Crystallisation, especially Steels with Reversible α-γ Transformations," by E. Valenta and F. Poboril. (Czecho-Slovakian Exchange Paper.)

(8) "A Study of Internal Stresses and Working Deformation in Grey Cast Iron," by Prof. Navarro Alcager. (Spanish Exchange Paper.)

(9) Italian Exchange Paper (subject and author to be announced later).

(10) "The Application of Electricity in the Foundry," sponsored by the electric supply companies.

(11) "Electric-arc Furnaces," by M. Boutigny.

(12) "Radiation Furnaces: Their Application in the Foundry and General Metallurgy," by M. George.

(13) "The Use of the Induction Furnace in the Steel Foundry," by L. Dewier.

(14) "The Improvement of Cast Iron by Heat-Treatment," by Prof. E. Piwowarsky.

(15) "Churned Iron and Soda-Ash Treatment," by Prof. Girardet.

(16) "The Development and Use of Refined and Alloyed Pig-iron in Great Britain," by G. T. Lunt.

(17) "The Part Played by Oxidation and Surface Tension in the Casting of Aluminium," by A. Portevin and M. Bastien.

(18) "The Use of the Rotary Furnace," by M. Boutigny.

(19) "Melting in the Cupola and Rotary Furnace," by Fr. Boussart and J. Goffart.

(20) "Industrial Applications of Low-Chromium-Content Irons," by A. Le Thomas.

(21) "Alloys Cast under High Pressure," by Dr. Jeniceck.

(22) "New Experiments on the Modulus of Elasticity in Cast Iron," by J. Challansonnet.

(23) "Metallic Losses encountered when Cupola Melting," by C. Henon.

(24) "A Study of Sand Ramming," by Fr. Boussart.

(25) The Properties of some Alloyed Special Irons," by Jean Challansonnet.

(26) "Soda-Ash Treatment in Iron and Steel Foundries," by A. G. Lefebvre.

(27) "Spongy Porosity and the Léonard Phenomenon," by M. Kagan.

(28) "Centrifugal Cleansing of Pig-iron," by E. Vroonen.

(29) "The Classification of Malleable Cast Iron," by Marcel Remy.

(30) Subject to be announced later, by M. Gysen.

(31) "Proportions to give to Fillets," by R. Paquet.

(32) "Tests for the Standardisation of 'Life' Tests," by M. Remy.

For further information our readers should write to either Mr. R. Deprez at 57, Rue de l'Académie, Liége, or Mr. T. Makemson at St. John Street Chambers, Deansgate, Manchester.

Oxy-Acetylene Welding

The accompanying illustration shows one of the new fleet of ten demonstration cars which The British Oxygen Company has just put into commission. These cars constitute a valuable new service from which both potential and present users of the oxy-acetylene process should derive great advantage.

Inside the car on a wooden frame shaped to hold them, there are ten small cylinders of gases lying down the length of the car with regulators, etc., facing the entrance. This is in order that the demonstrator can quickly fit up the blowpipe he wishes to use to the cylinders needed and demonstrate outside the van on a folding welding table provided. Welding, cutting, or leadburning can be demonstrated successively if required by hooking up the first blowpipe used and taking down the next required, which is ready for use coupled up to another pair of cylinders. Or, several operators can work simultaneously on the same or different classes of work.

Oxy-Acetylene Welding Demonstration Car by British Oxygen Company, Limited.

Relationships in Cast-Iron Test Results

By G. L. HARBACH

(*Concluded from page 72.*)

Relation between Tops and Bottoms of Bars

It is generally accepted that the bottom of a bar cast on end is stronger than the top and that modulus of rupture increases with decreasing span. These two factors were considered together, and the conclusions drawn from the same series of tests. The results are given in Tables IV, V and VI.

Comparing the results obtained from top and bottom halves of bars the latter are slightly higher in average strength but in no instance is the gain consistent. Individual bars gave results differing as much as 10 per cent., the higher strength not always being from the bottom half. Table V gives the results of two series of 14 bars each, one of which showed no difference in strength between tops and bottoms and the other showed the bottoms to be strongest by 1 ton. This is representative of the results generally obtained and leads to the conclusion that there is little difference in strength as a rule, but when there is a difference it is generally in the direction of higher strength in the bottom of the bar.

Tensile strength has not been considered so thoroughly as transverse, but it may be mentioned that out of six bars from an iron consistently close to 14 tons tensile, five did not vary more than 0.3 ton and the sixth gave 13.9 and 15.0 tons from top and bottom respectively. This appears to confirm the conclusion reached with regard to transverse, although the result of 15 tons is so high for that particular iron that it might be considered a freak.

To check further the effect of length of bar on strength, the top and bottom of a runner 9 ft. long and 2¼ in. dia. were tested at 30 in. span as cast, and the broken halves used for further tests. The extreme top and bottom ends were machined to 1.5 in. dia. for testing in transverse at 12 in. span and the other halves for tensile tests on 1.595 in. dia. The results obtained were:—

	Top.	Bottom.
		Tons per sq. in.
Transverse as-cast 2¼ in. dia., 30-in. span	23.0	23.7
Transverse machined to 1.5 in. dia., 12-in. span	24.5	21.8
Tensile 1.595 in. dia.	12.1	10.9
Brinell hardness Nos.	207	187

The "as-cast" result is doubtful as the sand had burnt on about ⅛ in. thick on the bottom bar and was considered as having no strength when the modulus of rupture was calculated—an allowance which the other results suggest was too generous. All three fractures of the bottom bars were more open than the top fractures. It is not suggested that these results are directly comparable with those of test-bars, owing to the difference in casting and cooling conditions, but they are the most extreme examples available of bottom in relation to top, and are included as a matter of interest chiefly because the results were contrary to expectations.

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4 I.B.F. "Cast Iron Sub-Committee Report," FOUNDRY TRADE JOURNAL, July 12, 1934, p. 27, and FOUNDRY TRADE JOURNAL, October 4, 1934, p. 204.
5 Pearce (J. G.). FOUNDRY TRADE JOURNAL, August 8, 1929, p. 101.
6 MacKenzie (J. T.). FOUNDRY TRADE JOURNAL, August 30, 1934, p. 129.
7 Hailstone (G.). "Journal of the Iron and Steel Institute," No. 2, 1914, p. 82.
8 "A.S.T.M. Symposium on Cast Iron," 1933, p. 57.

TABLE IV.—*Average Results of* 13 2-*in. by* 1-*in. by* 40-*in. Bars, Cast from the Same Mixture and Tested at* 36-*in. and* 12-*in. Spans.*

	Transverse Modulus of Rupture					
	Middle at 36"		Top Halves at 12"		Bottom Halves at 12"	
	Tons □"	%	Tons □"	% of 36" Mean	Tons □"	% of 36" Mean
Mean	21·5	100	22·7	105·5	22·9	106·5
High	23·7	110·5	26·8	124·5	26·6	124·0
Low	20·4	96·0	20·0	93·0	20·1	93·5
	Deflection.					
	Ins.	%	Ins.	% of 36" Mean	Ins.	% of 36" Mean
Mean	0·406	100	0·111	27·6	0·125	31·0
High	0·492	112	0·121	30·0	0·137	34·0
Low	0·332	82·5	0·091	22·6	0·084	23·3

TABLE V.—*Average Results of Two Sets of* 14 *Specimens,* 26-*in. by* 1·2-*in. Dia. Bars, Cast from the Same Mixture and Tested at* 18-*in. and* 12-*in. Spans.*

	Transverse Modulus of Rupture					
	Middle at 18"		Top Halves at 12"		Bottom Halves at 12"	
	Tons □"	%	Tons □"	% of 18" Mean	Tons □"	% of 18" Mean
First Set	26·0	–	26·5	–	27·5	–
Second Set	25·7	–	25·9	–	25·9	–
Mean	25·8	100	26·2	101·5	26·7	103·5
High	28·5	110·5	29·1	113	30·2	117
Low	24·3	94	23·0	89	24·7	96
	Deflection.					
	Ins.	%	Ins.	% of 18" Mean	Ins.	% of 18" Mean
First Set	0·201	–	0·121	–	0·125	–
Second Set	0·194	–	0·128	–	0·121	–
Mean	0·198	100	0·128	62	0·123	62
High	0·228	115	0·137	69	0·145	75
Low.	0·172	87	0·108	54·5	0·109	55

Effect of Span on Modulus of Rupture

In Table VI the results from three mixtures are shown so that high and low strength and percentage variations from the mean are no guide to the consistency of the mixture, but in Tables IV and V both sets of results were from the same mixture—although cast at different periods—so that, apart from the factors under review, they serve to show the relation between 2 in. by 1 in. and 1.2 in. dia. bars. Under the standard conditions of testing, both series show variations from 10 per cent. above to 5 per cent. below the mean, and the results of the short bars show wider variations, so, although there is a definite increase in average strength when the span is shortened, it is not consistent, and, in fact, occasionally the shorter bar is the weaker of the two. This is most marked in Table VI, which shows that the lowest results for top and bottom halves at 12-in. span are 1.6 and 0.4 tons below the lowest for the 24-in. span and the highest result was obtained from a 24-in. bar.

The following summarises the conclusions from Tables IV, V and VI:—

Bar.	Decreasing span		Strength altered. Per cent.			Deflection decreased. Per cent.
	From	To	Mean.	High.	Low.	
	in.	in.				approx.
2 by 1 in.	36	12	+6	+14	−2	72
1.2 in. dia.	24	12	+4	—	—	65
1.2 in. dia.	18	12	+2·5	+7	−5	38

Reviewing the results as a whole, it may be accepted that for any series of tests the average results are highest when the span is shortest and the greater the difference in span the greater the difference in strength, but the relationship is not sufficiently consistent to apply it with accuracy to any particular bar, although, if the limits are appreciated, it may be of use as shown below.

Dealing with the 1.2-in. dia. bars shown in Table V, as the most likely to be of practical importance, the results from 12-in. bars may be expected to be about 0.8 ton higher than the results from 18-in. bars, with the possibility that the difference may be ± 1.5 tons. Actually, the differences in individual bars were slightly wider as the high and low results, at 18 in. were not always from the same bars which gave the high and low results at 12 in., but invariably the average from each pair of bars fell within the limits shown. (This remark also applies to the results in Tables IV and VI for their respective spans, and also the deflection results in each table.) Assuming a pair of 1.2-in. dia. bars cast 26 in. long gave variable results when tested at 18 in., either with or without apparent flaws to account for the difference, the testing of each half would yield four more results, which could be calculated within known limits to the results at 18 in., thus allowing a more accurate conclusion to be drawn than would be possible from the first results. The factors required are 0.97 for the modulus of rupture and 1.6 for the deflection. Taking a pair of bars used in Table V, which gave the widest variation, as an illustration, the results were 26.9 and 24.8 tons at 18 in. (both being apparently sound), and 28.1, 27.4, 30.2 and 27.7 at 12 in. The mean at 12 in. was 28.35 tons, multiplied by 97, gave 27.4, which confirmed the higher of the two first results.

TABLE VI.—*Average Results of* 14 *Specimens of* 26-*in. by* 1·2-*in. Dia. Bars Cast from Three Different Mixtures and Tested at* 24-*in. and* 12-*in. Spans.*

	Transverse Modulus of Rupture							
	Middle at 24"		Middle at 12"		Top Halves at 12"		Bottom Halves at 12"	
	Tons □"	%	Tons □"	% of 24" Mean	Tons □"	% of 24" Mean	Tons □"	% of 24" Mean
Mean	26·3	100	27·3	103·7	27·3	103·7	27·4	104·1
High	32·0	121·6	29·7	113	29·2	111	31·0	118
Low	24·3	92·5	25·0	95	22·7	86·5	23·9	91
	Deflection.							
	Ins.	%	Ins.	% of 24" Mean	Ins.	% of 24" Mean	Ins.	% of 24" Mean
Mean	0·341	100	0·116	33·5	0·122	35·8	0·119	35
High	0·395	116	0·140	41	0·140	41	0·133	39
Low	0·293	86	0·098	28·7	0·100	29·4	0·107	31·4

Examination of Table VI shows that for bars tested at 12 in., and each half again tested at 12 in., no difference in average strength occurred. This confirms the experience of Pearce[1] that "the material on either side of a transverse break can be used with safety for further tests without risk."

The deflection results given in Tables V and VI were all corrected for errors in bar size, but as the load varies as dia.[3] and the deflection as dia.[4] *in the opposite direction*, once the corrected load has been calculated, three-quarters of the error in deflection is adjusted, and the remaining error is rarely significant. Actually, it is approximately 0.0017 in. for 0.01-in. error in dia. on the 1.2-in. dia. bar tested at 18 in. from the formula:—

$$\text{Corrected deflection} = \frac{\text{Actual deflection} \times \text{actual dia.}}{\text{Standard dia.}}$$

Relationship between Different Sizes of Test-Bars

This investigation was carried out to find in what way the strength of different sizes and shapes of test-bars compared, and naturally links up with the effect of section size on strength. From two sets of curves in the Paper by Pearce[3] the broad conclusion might be drawn that strength decreases as the section increases,

XUM

and the effect may or may not become more pronounced as the silicon rises (or strength falls), a variation which appeared to be dependent on factors apart from composition. With this in mind, it was decided to calculate the mean strength of different bars in groups of 1 ton tensile based on the strength of the 1.2-in. bar. The results obtained are tabulated in Tables VII and VIII.

It will be noticed that the results of only four 1-in. by 1-in. bars were available for comparison. This was due to the fact that this size of bar has rarely been used since the round bars were adopted, and in consequence the ratios shown cannot be accepted with the same confidence as those obtained from larger numbers of bars. Tests to determine the relationship between 2-in. by 1-in. and 1-in. by 1-in. bars were carried out about 20 years ago by the late G. Hailstone,[7] who concluded the factor for transverse breaking loads was 1.15 instead of the theoretical 1.33, which showed the 1-in. by 1-in. bar to be relatively the stronger of the two. The results in Table VII support this, but are insufficient to establish a ratio.

When round bars were used, it was soon realised that in transverse strength they were relatively stronger than rectangular bars. Bach[8] shows that variations also occur with other section shapes. Several workers have investigated the relation between 2-in. by 1-in. and 1.2-in. dia. bars. Again quoting from the same publication, the average ratio between 2-in. by 1-in. by 24-in. and 1.2-in. dia. for 39 sets of bars in triplicate is given as 0.84, and for other rectangular and round bars as 0.83, both being very close to the 0.85 shown in Table VII, and the results of Tables IV and V, which work out at 0.834. It may therefore be accepted that the 1.2-in. dia. bar is approximately 20 per cent. stronger than the 2-in. by 1-in. bar in transverse strength, although individual results may vary up to 15 per cent. or more about the mean.

Table VII.—*Transverse Strength Relationship between Various Test-Bars. Mean Result of* 1.2 *Dia. Bar taken as* 100 *for each Group.*

No. of Bars	1·2" Diam Mean Tensile Tons/sq. in.	.875" D No. of Bars	.875" D Mean	1·655" D No. of Bars	1·655" D Mean	2·2" D No. of Bars	2·2" D Mean	2"×1" No. of Bars	2"×1" Mean	1"×1" No. of Bars	1"×1" Mean
1	9·3	22·7	1	105	-	-	1	82	-	-	-	-
7	12·7	25·8	5	112	6	92	-	-	3	85	1	105
3	13·7	28·3	1	104	1	93	1	86	2	87	1	86
7	14·3	27·3	5	109	7	91	1	93	4	84	1	86
4	15·3	28·8	3	107	3	92	2	89	2	83	1	84
2	16·2	31·6	2	103	-	-	2	84	-	-	-	-
3	17·7	29·2	3	109	3	93	1	96	1	91	-	-
4	18·6	33·2	3	103	3	95	-	-	-	-	-	-
4	19·5	33·7	3	106	2	92	2	84	-	-	-	-
2	22·1	38·6	2	98	2	94	-	-	-	-	-	-
	Mean		28	107	27	92	10	87	12	85	4	90
	High *		-	117	-	106	-	103	-	98	-	105
	Low *		-	96	-	80	-	82	-	71	-	84

* Taken from Original Bars.

Considering the tensile strength, both the 2-in. by 1-in. and 1-in. by 1-in. bars show a higher ratio than for transverse—92 and 94, against 85 and 90 respectively—which again indicates the lowering effect of rectangular sections on transverse test results, and shows why the curve of transverse/tensile ratios is lower for 2 in. by 1 in. than for round bars in Figs. 1 to 4. Whilst the 2-in. by 1-in. transverse strength is rather lower than the 2.2-in. dia. bars, the tensile is equal to the 1.65-in. dia. bar—an increase of about 8 per cent., making the ratio to the 1.2-in. dia. bar 0.92 instead of 0.85 as in transverse. If the 1.65-in. dia. by 24-in. bar is adopted with a view to giving the same breaking loads as 2 in. by 1 in. by 36 in., it would need to be reduced to 1.6-in. dia. This would not affect the close tensile results, and the span/diameter ratio would then be exactly the same as the 1.2-in. dia. bar.

Turning to the results of round bars, it was expected that, as the strength increased, the percentage difference in each size of bar compared with the 1.2-in. dia. bar would decrease, but, except in very low- and very high-strength irons, such an effect is not noticeable, and for practical purposes the mean of each series is applicable to all the usual grades under the conditions of manufacture and testing. There is a steady reduction in strength as the section is increased, and, apart from the 0.875-in. dia. bar, which seems to gain a little more in tensile than transverse by the smaller section, both strengths are reduced to the same extent. Factors, taking the 1.2-in. dia. bar as standard, are the mean results divided by 100.

Effect of Section Size on Strength

The fact that cast iron is lowered in strength by increasing section is well known and may, by undue emphasis, be used to its detriment, but it is often overlooked that the same effect occurs to some extent in all metals both cast and forged. Moreover, it is probable that early investigations from which the conclusion is drawn were carried out on irons of lower strength and made with less scientific control than modern irons, both factors tending to give exaggerated results. In support of this view the following may be quoted from the A.S.T.M. Symposium on Cast Iron, dealing with mass effect: "Irons produced by foundries with adequate metallurgical control vary less in properties from section to section than irons formerly used"—an opinion held by the B.C.I.R.A. and other workers in this field.

An early experiment to study the effect of varying section and to compare a 1 per cent. nickel iron with an unalloyed iron was carried out by casting two "pyramid" bars 14 in. long tapering from a point to 4 in. square. The analysis of the iron as tapped was:—T.C., 3.17; Si, 1.02; Mn, 0.97; S, 0.09, and P, 0.3 per cent.

Table VIII.—*Tensile Strength Relationship between various Test-Bars. Mean Result of* 1.2 *in. Dia. Bar taken as* 100 *for each Group.*

No. of Bars	1·2" Diam Mean Tensile Tons/sq. in.	.875" D No. of Bars	.875" D Mean	1·655" D No. of Bars	1·655" D Mean	2·2" D No. of Bars	2·2" D Mean	2"×1" No. of Bars	2"×1" Mean	1"×1" No. of Bars	1"×1" Mean
1	9·3	1	114	-	-	1	88	-	-	-	-
7	12·7	3	114	2	90	-	-	1	90	1	97
3	13·7	2	117	1	92	1	86	1	105	1	86
7	14·3	3	109	4	90	1	91	4	91	1	98
4	15·3	1	108	1	98	1	83	2	91	1	94
2	16·2	2	111	-	-	2	93	-	-	-	-
3	17·7	-	-	-	-	-	-	-	-	-	-
4	18·6	-	-	1	93	-	-	-	-	-	-
4	19·5	1	94	1	94	-	-	1	87	-	-
2	22·1	2	101	2	94	-	-	-	-	-	-
	Mean	15	110	12	92	6	89	9	92	4	94
	High *	-	128	-	98	-	97	-	105	-	98
	Low *	-	94	-	87	-	83	-	86	-	86

* Taken from Original Bars.

To one shank was added 1 per cent. of 50 per cent. ferro-silicon, and to another 1 per cent. nickel. The final silicon content was 1.46, and the nickel 0.9 per cent., so that the compositions were not quite in balance for true comparison, and later experience placed the ratio of nickel to silicon at 3 to 1 instead of 2 to 1 as sought in this experiment. The pyramid bars were slotted along the middle of two opposite sides and then broken across by a wedge. One half of each was planed flat for Brinell-hardness tests which gave the results shown in Fig. 8. The fractures were also compared and the depth of chill and mottle in each clearly indicated the lack of balance between nickel and silicon. The nickel iron showed the more chill and was slightly harder throughout, but the grain size of both bars was practically identical except for the unalloyed iron being the more open at the centre of the

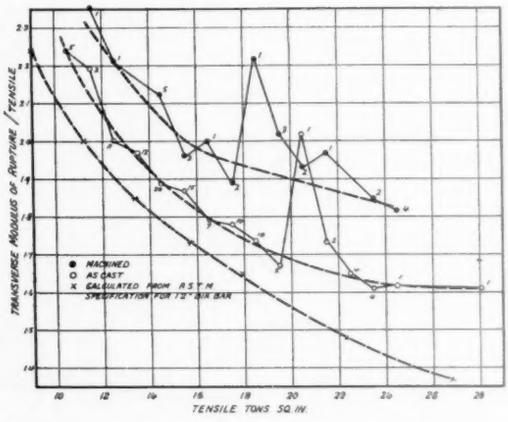
TRANSVERSE MODULUS OF RUPTURE / TENSILE
TENSILE TONS SQ. IN.
● MACHINED
○ AS CAST
X CALCULATED FROM A.S.T.M. SPECIFICATION FOR 1·2" DIA. BAR

Fig. 7.—Transverse, Tensile Results and Ratios, Combined Curves.

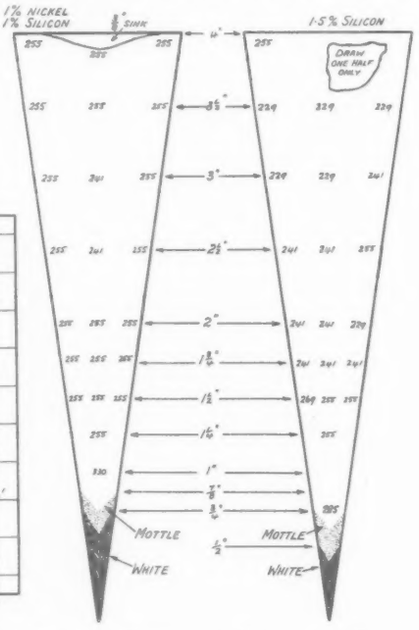

Fig. 8.—Effect of Nickel on Brinell Hardness.

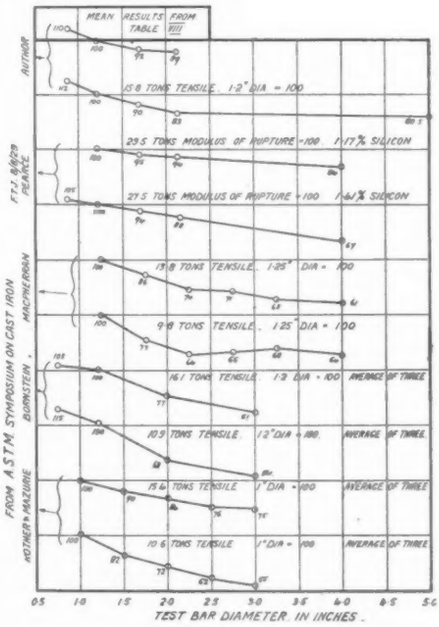
MEAN RESULTS FROM TABLE VIII
AUTHOR
15·8 TONS TENSILE 1·2" DIA = 100
29·5 TONS MODULUS OF RUPTURE = 100 1·17% SILICON
27·5 TONS MODULUS OF RUPTURE = 100 1·46% SILICON
19·8 TONS TENSILE 1·25" DIA = 100
9·8 TONS TENSILE 1·25" DIA = 100
16·1 TONS TENSILE 1·2 DIA = 100 AVERAGE OF THREE
10·9 TONS TENSILE 1·2" DIA = 100 AVERAGE OF THREE
15·6 TONS TENSILE 1" DIA = 100 AVERAGE OF THREE
10·6 TONS TENSILE 1" DIA = 100 AVERAGE OF THREE
FROM A.S.T.M. SYMPOSIUM ON CAST IRON
TEST BAR DIAMETER IN INCHES.

Fig. 9.—Effect of Section Size on Strength (Series of Curves).

3-in. and 4-in. sections. It is probable that if the silicon had been low enough to match the chill of the nickel iron it would have been even closer to the nickel iron in hardness and grain size. Enough information was obtained to conclude that nickel addition promoted uniformity in varying sections, but the iron already in use was not affected in hardness or grain size to the extent anticipated.

The mean results given in Tables VII and VIII show the strength relationship between the four standard test-bars in use, and it was recently decided to investigate the effects of further increase in section. With this end in view a 14-in. by 5-in. dia. bar was cast to represent the thickest section likely to be required in the mixture used. Five bars were cut—two from the extreme edge, one from the centre and two as near the centre bar as possible—and machined to 1.2 in. dia. After breaking in transverse the bottom halves were machined to 0.798 in. dia. tensile test-pieces and tested, and also tested for Brinell hardness. From the results obtained the strength of the 5-in. dia. bar was calculated. The results, and those of a complete set of bars from the same mixture, are shown in Figs. 9 and 10. The former includes the results of other

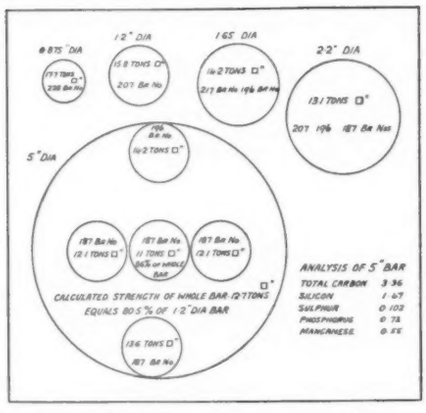

FIG. 10.—TENSILE STRENGTH AND BRINELL HARDNESS OF TEST-BARS FROM 0.875 IN. TO 5 IN. DIA.

workers for comparison. From this it will be seen that whilst increasing section invariably causes loss of strength, in most cases there is less relative loss with the high-strength irons, and the 5-in. dia. bar from a 15- to 16-ton iron compares favourably with the results of other investigators. The loss is only about 20 per cent. when the section is increased from 1.2 in. to 5 in., from which the conclusion may be drawn that under the conditions of manufacture, when strength is a primary consideration, the iron used will not be seriously affected by thick sections.

The results given in Table III have already indicated that the loss in transverse strength caused by machining to various depths was not severe, and Fig. 10 shows that even when the 5-in. dia. bar was machined to 0.798 in. dia. (2.5 per cent. of the original area) it still retained 86 per cent. of the tensile strength of the original bar. This confirms the results given by Pearce,[5] which showed that a bar 0.2 in. dia. machined from a 2.2-in. dia. bar retained 75 per cent. of the tensile strength of the original bar and gives a conclusion in definite values to the popular statement "the nearer the centre the weaker the iron." In this connection it may be mentioned that fractures are not always reliable guides to strength, as the centre of a thick section may show a coarse grain without necessarily being weak and thin sections of weak irons, although close grained, are not strong.

Conclusion

The investigations carried out were in the main prompted by curiosity regarding queries and popular ideas in connection with cast iron. The Paper has been prepared with a view to answering some of the queries and giving, where possible, quantitative values to the influence of various factors, the effects of which are generally appreciated but apt to be over-estimated.

The author feels there is scope for publicity by manufacturers in the direction of improving the acquaintance of users with the properties of cast iron in general and modern cast irons in particular. Probably this could best be done by a publication similar to the American Society for Testing Materials and the American Foundrymen's Association Symposium on Cast Iron, compiled in collaboration with engineering bodies. Furthermore, it is essential that the high-strength irons be included in a national specification to show that British ironfounders are not backward compared with other countries.

In conclusion, the author wishes to thank Mr. J. T. Graham (Director, Manufacturing and Engineering), Messrs. Worthington-Simpson, Limited, Newark, for permission to give the results embodied in the Paper, and several of the staff who have willingly assisted in the preparation of test-bars and illustrations, also acknowlegments are possibly due to other investigators whose work may have been unwittingly duplicated.

The Institute of Metals

ANNUAL AUTUMN MEETING AT NEWCASTLE-UPON-TYNE

As previously announced, the twenty-seventh annual autumn meeting of the Institute of Metals will be held in Newcastle-upon-Tyne from September 9 to 12. An influential reception committee has been formed to carry out the necessary arrangements, which are outlined in the following programme.

Monday, September 9.

7.15 p.m.—Fourteenth autumn lecture on "Metal Melting—Its Effect on Quality," by Dr. H. W. Brownsdon (Member of Council), in the King's Hall, Armstrong College. The lecture will be given in concise form and will be followed by a general discussion on the subject.

9.45 p.m.—Informal gathering of members and their ladies in the University Union, College Road. (Light refreshments.)

Tuesday, September 10.

10 a.m.—A civic welcome will be given to the Institute by the Rt. Hon. the Lord Mayor of Newcastle-upon-Tyne (Councillor R. S. Dalgliesh), supported by the Sheriff, in the King's Hall, Armstrong College.

10.30 a.m.—General meeting of members in the new Mining Lecture Theatre, Armstrong College, for the presentation and discussion of Papers.

11 a.m.—Ladies will visit the Castle and Black Gate after assembling at the College Archway in College Road.

2 p.m.—Members will leave College Road for visits to the following works:—(*a*) Sir W. G. Armstrong Whitworth & Company, Limited; (*b*) Dunston Power Station of the North Eastern Electric Supply Company, Limited; (*c*) Vickers-Armstrongs, Limited (visitors must be of British nationality); (*d*) Ladies' visit to Cremona Toffee Works.

8.30 p.m. to midnight.—Civic reception and dance at the Old Assembly Rooms. Members and ladies will be received by the Rt. Hon. the Lord Mayor and Lady Mayoress of Newcastle-upon-Tyne (Councillor R. S. Dalgliesh and Mrs. Dalgliesh).

Wednesday, September 11.

10 a.m.—General meeting in the new Mining Lecture Theatre, Armstrong College.

10 a.m.—Ladies will visit Durham City and be shown over the Castle and Cathedral. Assemble in College Road.

2 p.m.—Members will leave College Road for visits to the following works:—(*e*) North Eastern Marine Engineering Company, Limited; (*f*) C. A. Parsons & Company, Limited; (*g*) A. Reyrolle & Company, Limited; (*h*) Wallsend Shipyard (Swan Hunter & Wigham Richardson, Limited) (visitors must be of British nationality).

8 p.m.—Members and their ladies will be entertained to dinner at the Royal Station Hotel.

Thursday, September 12.

9.30 a.m.—Motor coaches will leave College Road for a whole-day excursion. A short visit will be paid to the famous Chesters Museum at Chollerford, following which the Roman Fort at Borcovicus, and adjacent parts of the Wall, will be inspected. Mr. I. A. Richmond, M.A., of Durham University, has kindly consented to explain these to the visitors. Luncheon will be served at the Hexham Hydro at 1 p.m. The party will arrive back in Newcastle at approximately 6 p.m. The charge for the excursion, inclusive of lunch and tea, will be 11s. per person.

PAPERS

The following is a complete list of the Papers that have been offered for the Autumn Meeting:—

698. "Note on the Effect of Interrupted Straining on the Elongation of Lead," by J. C. Chaston, B.Sc., A.R.S.M.

699. "X-Ray Study of Copper-Silver Alloys," by Prof. E. A. Owen, M.A., D.Sc., and Joseph Rogers, Ph.D.

700. "An X-Ray Investigation of Certain Copper-Tin Alloys," by Prof. E. A. Owen, M.A., D.Sc., and John Iball, Ph.D.

701. "Observations of the Porosity and Segregation of Two Bronze Ingots," by N. P. Allen, M.Met., D.Sc., and S. M. Puddephat, B.Sc.

702. "Corrosion below Discontinuous Oxide Coatings, with Special Reference to Magnesium," by K. G. Lewis, M.Sc., and U. R. Evans, M.A., Sc.D.

703. "Metal Losses in Melting Brass and Other Copper Alloys," by Maurice Cook, M.Sc., Ph.D.

704. "The Properties of Some Special Bronzes," by Prof. D. Hanson, D.Sc., and M. A. Wheeler.

705. "The Inter-Relation of Age-Hardening and Creep Performance. Part I.—The Age-Hardening of Nickel-Silicon-Copper Alloys." With an Appendix on the Relationship of Time, Temperature and Concentration as Factors in Age-Hardening," by C. H. M. Jenkins, D.Sc., A.R.S.M., and E. H. Bucknall, M.Sc.

706. "The Determination of Certain Phase Boundaries in the Silver-Zinc Thermal Diagram by X-Ray Analysis," by Prof. E. A. Owen, M.A., D.Sc., and I. G. Edmunds, M.Sc.

707. "Note on the Failure of a Gold Fuse in Contact with Nickel-Chromium Alloy," by M. C. Caplan, B.Sc.

708. "Production of Powdered Alloys of Low Melting Point," by R. W. Rees, B.Sc.

709. "The Protection of Magnesium Alloys against Corrosion," by H. Sutton, M.Sc., and L. F. Le Brocq, B.Sc.

710. "Electron Diffraction Examination of Protective Films deposited on Magnesium and Magnesium Alloys by the R.A.E. Dichromate Process," by H. G. Hopkins, A.R.C.S.

711. "Alloys of Magnesium. Part III.—Constitution of the Magnesium-Rich Alloys containing Aluminium and Cadmium," by J. L. Haughton, D.Sc., and R. J. M. Payne, B.Sc.

712. "An Investigation of the Nature of Creep under Stresses produced by Pure Flexure," by H. J. Tapsell, A.C.G.I., and A. E. Johnson, M.Sc.

713. "Note on the Tarnishing of Liquid Metals as studied by X-Rays," by Hugh O'Neill, D.Sc., M.Met., and G. F. Farnham, Ph.D., M.A.

XUM

A Note on the Influence of Temperature Gradients in the Production of Steel Castings

By GEORGE A. BATTY

(*Concluded from page 67.*)

Temperature Gradient for a Liner Casting

Fig. 8 presents as a full line a hypothetical temperature gradient for the example under discussion, the line sloping downwards from left to right, such inclination being indicative of substantial feeding potentiality by the superimposed "riser." The broken line on the same figure is a hypothetical temperature gradient for the same casting bottom gated at the light section, with the collar or flange and the feed head at the top. In attempting to produce such a casting in such a manner it is to be assumed that a fairly rapid pouring rate would be ensured and that the metal temperature would not be unduly high.

Admittedly, Fig. 8 is conjectural, but the suggested gradients are based upon observation of the pouring of many castings and the examination of a number of castings which have been "bled," either intentionally or fortuitously. In scrutinising the temperature gradients it is not to be assumed that anything but an average

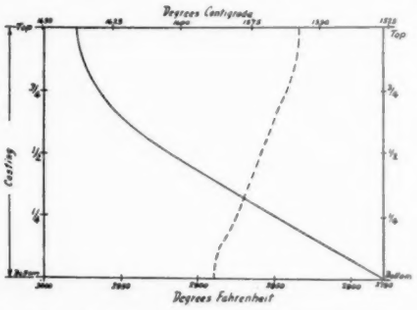

FIG. 8.—A HYPOTHETICAL TEMPERATURE GRADIENT CURVE FOR THE CASTING SHOWN IN FIG. 7.

for the section is intended to be expressed. It is recognised that a temperature gradient exists from surface to midsection and, in a horizontal direction, from gate to parts remote from the gate in castings which are poured "on the flat."

The temperature gradient of the mould—really a relatively thin envelope of mould surrounding the casting—is much more difficult to visualise. Briggs and Gezelius[1] have shown that throughout a considerable part of the cooling of a cast 6-in. dia. sphere the temperature of the sand at a distance of ⅛ in. from the mould-metal interface was only about 150 deg. Fah. less than the temperature at the centre of the sphere. Despite the low thermal conductivity of sand, the mould takes a considerable amount of heat from the metal in transit, as is demonstrated by castings accidentally "bled" as the result of a break-out near the gate. Such remanent shells show an envelope of considerably greater thickness formed at the upper levels than at the lower levels close to the ingate, and demonstrate the potency of the mould as a coolant in relation to pouring temperature, pouring rate and section thickness.

It is obvious that the potency of the mould as a cooling agent decreases sharply as section thickness increases, but the potency of the mould increases as the distance to be traversed by metal within the mould increases. Thus, the temperature gradient which can be created in a cast 6-in. cube, suitably headed, is very slight as compared with that attainable in a cast piece 6 in. by 6 in. by 72 in. long produced on the partial-reversal method. (For detailed descriptions of various mould manipulative methods, partial and total reversal, the reader is referred to previously published Papers by the author.[2])

American and British Practices

In discussing temperature gradients, the author has adhered to examples of castings made under conditions which largely govern American practice. In that country little or no moulding material is used that has the characteristics of either the British "compo" or the Continental European "chamotte," and it is fairly general practice to gate into the lower levels of the mould. Top-pouring such as may be adopted with "compo" moulds is relatively rarely used in American foundries.

The temperature gradients in mould and metal which may be created by top-pouring are more favourable than those attainable by bottom-gating unmanipulated moulds, but are not as favourable as those to be achieved by bottom gating and "reversing" the mould after pouring is completed. A fine example of good gating method is provided in Hatfield's Paper[3] delivered to the American Foundry Convention in 1934. The heading of the casting is also very interesting, as it shows an appreciation of the necessity for a large volume of feed metal when blind risers are used which are not directly served by ingates. The filling of such risers produces in them—as it does in ordinary open heads which are not filled from the top—an adverse temperature gradient in both mould and metal. It is, therefore, necessary to have risers of such dimensions, in relation to the sections with which they are connected, that their reserve of temperature is adequate to maintain fluidity of their interior metal over a period of time sufficient to ensure the solidification of the casting; or, at least, of that part of the casting which each riser is devised to feed.

Design and Manipulatable Moulds

The temperature gradients in a bottom-gated casting are bound to be adverse, and only a locally favourable condition can be created by top-filling the feeding heads. Reverting to the part of a casting shown on Fig. 4 and including the feeding head, a temperature gradient of the type postulated in Fig. 9 would probably be produced a short time after pouring was completed. The local favourable temperature gradient within the feed head will ensure that the casting proper immediately below the riser will appear sound when the head is removed, but the adverse nature of the temperature gradient for the lower three-quarters of the height of the casting—amplified by the adverse temperature gradient of the mould, resultant upon bottom-gating—points to the conclusion that the casting cannot be expected to be free from mid-section unsoundness in the lower levels. Thus it must be realised that design is a factor of very great importance and that for castings produced in unmanipulatable moulds—moulds that cannot be "reversed" after pouring—the taper or "wedge" type of section, small end down, should merit the attention of designers as being complementary to the production of integrally-sound cast structures.

[3] Hatfield, Dr. W. H. "Steel Castings." "Trans. American Foundrymen's Association," 1934.

In castings which are of a size that can be produced in manipulated moulds—using one of the reversal systems—there does not exist to the same extent the necessity for tapering-wall sections, the creation of favourable temperature gradients in both mould and metal being competent to overcome, to some considerable extent, the normal difficulty of feeding a section. There is, however, very definitely a limit to what can be done by mould manipulation, this limit being prescribed by practicable pouring temperature and pouring rate.

One of the features of promoting controlled directional solidification, as the result of properly-organised temperature gradients, which appeals to the steelfounder is the economy of feed metal. It is admitted that the discovery of the extent to which this economy could be carried was accidental—but for the accident, unnecessarily-large feeding heads might have been continued in use—and that the early applications of mould reversal were successful attempts to cure defects which were apparent in certain castings immediately the risers were removed. The temperature-gradient theory is built upon the practical results arrived at by manipulating moulds after pouring is completed, is applicable with beneficial results to castings made in moulds that cannot be so handled, as it leads the practical foundryman to a more correct appreciation of the functions of gates and heads.

A system of step-gating may be considered as being of less efficiency than mould reversal, but more efficient than bottom gating, in promoting soundness of cast structure.

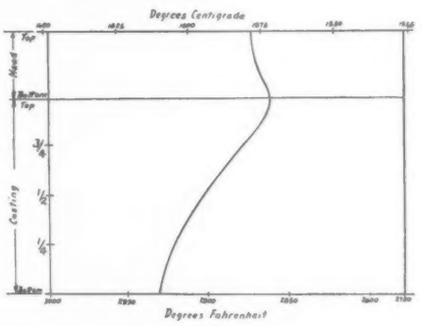

FIG. 9.—TEMPERATURE GRADIENT IMMEDIATELY AFTER CASTING.

Chills and Controlled Directional Solidification

The concept of perfect progressive solidification, from bottom to top in orderly continuity, is one that must be discarded, because of its utter impracticability; but controlled directional solidification is, for certain types of castings, an implement available to the founder. The means described[2] for achieving the desirable condition by "reversing" moulds or by a good system of gating and heading must be amplified by "chilling" isolated masses, pads, or bosses that cannot conveniently be reached by feed metal. For reasons which are apparent to most practical steel foundrymen, the author disapproves the use of internal-chills—variously described also as residual, cast in, remanent—in locations which can effectually be treated by external chills. It is conceded that in some instances an external chill cannot be used, and that nothing but an internal chill will achieve the desired result.

In promoting controlled directional solidification, external chills can be made to function efficiently upon parts that could never be adequately dealt with by internal chills, and this without the dangers of blows and the heterogeneities resultant upon the use of cast in denseners. The designing, as to shape and weight, of external chills in relation to the parts upon which they are imposed is an infant art, but is one which will be developed to the benefit of both castings and founders. The shape of

the chill must be such that it will not promote a sharp line of chill effect. It should be devised to take care of that excess of cast metal which is imposed on the general structure as a boss or pad without interfering with the whole projected scheme of solidification. If the chill be excessive in its effect, it may tend to negative other means taken to ensure an ordered and progressive solidification by closing the avenue through which feed metal should reach other parts of the casting.

The weight of the external chill must be related to the amount of heat it may have to take up from "metal in transit" as well as to the amount of heat it is devised to take from the "metal at rest" when the mould is full. It seems probable that the designing of efficient external chills will be arrived at empirically, and will be an art for some considerable time before sufficient fundamental knowledge is amassed to warrant precise scientific definition.

While chilling may be used to mitigate the dangers attendant upon concentrations of metal which cannot be fed from risers, the fact remains that the designer can, if willing, do much to eliminate the necessity for such costly foundry expedients. Heuvers[4] has suggested variations from orthodox practice in design which make a distinct appeal to the steelfounder, but it must

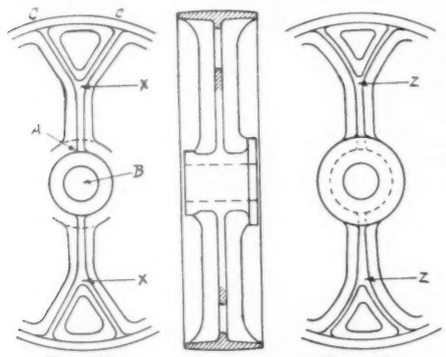

Fig. 10A. Fig. 10B.

Figs. 10A and 10B.—Lorry-Wheel Design of the Y Type.

be remembered that some inescapable features of design tend to create "hot spots," which, in turn, tend to promote either internal cavities or externally visible tears, or both.

Hot Spots

The founder rightly insists upon radiused junctions where two sections of metal would, otherwise, produce sharp corners or angles of sand projecting into the metal. The imposition of the fillet produces a local concentration of metal that must either be fed or chilled to ensure complete soundness. Internal hot tears or enclosed pipe are evidence that "humps" have occurred in the temperature gradient—if it was generally of a favourable type—or that the temperature gradient was generally of an unfavourable nature.

"Hot spots" are most likely to form at the ingate. Simple modifications of gate design appear, superficially, to cure the trouble, but it must be said that in many cases the "cure" is more apparent than real. The casting merely appears to be sound on the surface when the gate is removed, yet there may be a mid-section unsoundness. Such a localised deficiency may be a commercial defect in certain types of castings, whilst in others it is a metallurgical defect of no serious commercial significance.

On many types of castings, poured in the orthodox way, it is easy to locate the hot spot outside the casting by gating into a main riser. Valve bodies and flanged fittings have a pronounced tendency to exhibit leaks either at the radiused junction of flange and body or at a bolthole when gated at the edge of a flange. This bespeaks, of course, a crack or tear which extends to the bore of the casting. Such a tear or crack is due to a gate hot-spot, and the trouble can readily be cured by gating into the base of a lumped riser—sometimes called a face riser or elbow head—on the face of the flange. Such a riser should be at least twice as thick as the flange upon which it is imposed, in order that the centre of the mass—the last to solidify—is outside the casting. This procedure may necessitate longer coreprints than are normally provided, but the small expense of alteration to pattern and corebox is generally a good investment.

Box-like Castings

The tendency of box-like cast structures to tear at the corners is well known, and this tendency persists, even though the metal section is uniform, the external contour paralleling the internal radius. In such an example is demonstrated the effect of disproportion of metal to sand. The corner or "angle" of sand, even though apparently suitably radiused, is heated on two sides; it is subject to nearly twice the thermal attack that is imposed on the sand forming plain faces and it cannot take heat from the metal at the same rate as does the sand in contact with plain plates of metal.

Every so-called internal angle is, therefore, potentially a hot spot. These local humps in the general temperature gradient may generally be avoided by face-nailing the fillets, but a nice discrimination is necessary in prescribing the amount of such chilling. By "face-nailing" is meant the use of short, flat-headed nails, inserted until the heads are flush with the mould face. The heads do not project into the casting to become, thereby, internal chills. The application of this simple remedy is not always practicable because of pattern construction.

Mould Effect

Thus far the author has treated the subject in relation to the influence of gating and heading methods, together with mould manipulation, in promoting soundness in the cast structure which, in other words, is freedom from external tears and internal shrinkage cavities. It appears desirable to emphasise the effect of the mould—which is affected by metal in transit—upon the progress of solidification of the casting, because the literature pertaining to the production of steel castings has, hitherto, hardly touched upon the matter.

The extent of this effect is demonstrated by castings produced on one of the reversal methods where, by mould manipulation, the temperature gradients of both mould and metal are disposed in the correct direction.

At temperatures above the liquidus, steel is believed to behave as a true liquid, and McCance[5] gives the figure 0.00039 contraction per deg. C. It therefore follows that if what are ultimately to become the upper levels of the mould can be considerably heated by the relatively slow pouring of hot metal at a rate which, while sufficient to ensure a cleanly-run casting, considerably cools an appreciable amount of the metal, the mould is made to conserve heat in a graduated manner and control, directionally, the solidification of the casting.

Such conservation of temperature, particularly in the heads of totally-reversed castings, will, despite the high temperature of the upper levels of metal, result in adequate feeding from a relatively small reservoir or feed head. Cases have been noted where risers delivered as much as 35 per cent. of their volume to the casting, this being approximately equal to 3.5 per cent. of the volume of the total metal in mould. This figure of 3.5 per cent. is somewhat higher than the average contraction, measurable as pipe, in castings examined by the writer. To state the matter in another way, certain castings have been produced, ranging in weight from 1½ to 9 cwts., with a discard of only 6.5 per cent. Admittedly, these castings were made on the total-reversal method and every precaution was taken to promote conditions that would give a high yield, yet it may be said that castings of a similar type and larger in size were consistently made on the partial-reversal method, with an average yield of over 85 per cent. of metal in mould.

Post Solidification Temperature Gradient

The temperature gradients in castings at temperatures below solidification point must be a study separate from the matters discussed in the foregoing part of this note. Cold cracking is probably more to be associated with design than with moulding and pouring procedure. This statement is made because some designs have been noted which consistently developed such stresses in the castings as to lead to a considerable proportion of loss by cold cracking, but only small losses by hot tearing.

Fig 10A indicates the design of a truck wheel which was common a number of years ago, in the era of the solid-rubber tyre. Fig. 10B shows the modification of spoke design which overcame the trouble of cold cracking of the spokes. It should be noted that the only modification was the alteration of the shape of the

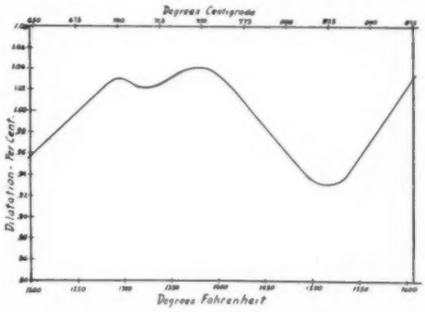

Fig. 11.—Dilatation Curve of the Steel used for Making the Castings shown in Fig. 10.

spokes, the hub and rim remaining the same in both designs. The spokes, six in number, are of cruciform section, Y-type, and split to give twelve junctures with the rim and mid-web. In the straight Y-type, Fig. 10A, these junctures were equally spaced. In the curved Y-type (Fig. 10B) the distance across the top of the Y was slightly greater than the distance between the tips of two Y's.

The wheels were gated at the hub, thus ensuring that the casting was gated into its heaviest section, and also that distortion was reduced to a minimum by providing that the metal at any two or more parts of the casting equidistant from the centre be of the same temperature, or as nearly so as possible, at the moment the mould is filled. This provision seems necessary on such castings as truck wheels, which are of light general section and which must be as nearly as possible in balance after machining. It is not so important on heavier castings such as gear blanks.

The chief trouble experienced in the production of the wheels having the straight Y-type spokes was a pronounced tendency to cold-cracking either at the points marked X or at A (Fig. 10A). Relatively few of the castings failed by reason of hot tears at these locations, and the magnitude of the residual stresses obviously varied in different castings. Some would cold-crack during cleaning operations, and the practice of heat-treating—a straight normalising—before fettling did not entirely eliminate the trouble. As a matter of fact, a number of fully-machined castings were known to develop the characteristic crack in transit, by rail, from foundry to customer.

[4] Heuvers, A. "Was hat der Stahlgeber dem Konstrukteur uber Lunerk—und Ribbildung zu sagen?" "Stahl und Eisen," No. 35, 1929.

[5] McCance, Dr. A. Foundry Trade Journal, December 27, 1928.

XUM

It is believed, by the author, that the tendency to crack was increased by machining, the removal of metal from the face of the tread and from the bore adversely affecting the residual stresses which, previous to machining, were not so remote from equilibrium as to promote a crack. This detail will not be discussed at length in the present Paper.

A scrutiny of the defective castings showed that in an overwhelming majority of the examples, a crack occurred at or near a point of metal concentration. Any deviation from the practice of gating at the hub aggravated the trouble, as well as introducing other deficiencies.

Visualising the temperature gradients—in this case, horizontally from hub to rim—it is apparent that at the moment the mould is filled the hub consists of the hottest metal contained in the hottest part of the mould. As the distance from hub increases, the temperature of both metal and mould decreases. While this is satisfactory from the viewpoint of securing adequate feeding from a riser imposed on the top of the hub, it has certain adverse implications when the design is studied in relation to dilatation phenomena. A dilatation curve, typical of the steel in which these castings were produced, is shown in Fig. 11.

Remembering that pronounced temperature gradients, correctly disposed for feeding, exist in both metal and mould, and that the metal temperature at the hub is probably at least 66 deg. C. higher than at the rim, solidification—and subsequent cooling—proceeds selectively from rim to hub. The rim, being in contact with cool mould, cools down relatively rapidly, and, down to 840 deg. C., is constricting. In the early, and most rapid, part of this period the hub and the inner ends of the spokes are conceivably so hot as to respond readily to the stress without incurring any pronounced residual influence. At a later stage in the cooling of the casting the rim will be passing through the range 840 deg. C. to 680 deg. C., and will be expanding while the inner parts of the casting—hub and parts of the spokes—are constricting and contracting. It was in this thermal period that the few cases of hot tears at A (Fig. 10) were believed to be generated.

The significant points to be considered, in relation to design, are marked XX on Fig. 10A. All the way down to shop temperature the rim precedes the remainder of the casting in cooling, and in aggregation of strength down to the lower end of the blue-brittleness range. The points XX—and similar locations diametrically opposed on the other spoke—became practically fixed points in their relation to the rim at CC, while the distance between them should decrease with falling temperature.

Thus, in the later stages of the cooling of the casting, the spokes were placed pronouncedly in tension of such magnitude as to lead to cold-cracking in far too many instances.

It became apparent that the prime necessity was to permit the points XX to move closer together in as full accord as possible with the normal uninterrupted contraction of cast steel. The design was accordingly modified to produce what is shown on Fig. 10B. The head of the Y, Fig. 10B, is produced as two curved members, each of which is of lighter section than the single member of the Y.

Given the same temperature gradients as the casting of the straight Y type, the points ZZ could get closer together, the curved spoke-members deforming under the tension of the contracting "inner" parts of the casting. To avoid any misconception, it should be stated that the curved spoke-members were of the same cross-section as those of the relative parts of the straight Y-spokes. The ability of the curved upper members to straighten—that is, to assume a larger radius—entirely eliminated the cold-cracking trouble, as well as the more rare

(*Concluded in next column.*)

(*Concluded from previous column.*)

occurrence of hot-tearing at the junction of a spoke with the hub.

This is the only example of design modification that the author proposes to submit in relation to the prevention of cold-cracking. Others could be cited, and it is believed that most practical foundrymen could, from the wealth of their experience, quote instances of difficulties encountered. It is hardly possible to entertain the hope that all such difficulties could be overcome in a manner so simple as that which effected the cure in the case of the lorry wheel.

No attempt will be made by the author to summarise, as it is his opinion that the matter is too complex—despite the simple examples chosen for discussion—to admit of comprehensive accuracy. It is to be remembered that each casting presents its own peculiar problem and, while castings may be classified in types, seemingly small variations affect materially the classification.

For inability to clothe the concepts in words that will be explicit to all, the author tenders his apologies, and undertakes to deal—within his limitations—as fully as possible with the matters that are bound to arise in the discussion.

Aluminium Alloys

CREEP CHARACTERISTICS

At the recent annual meeting of the American Society for Testing Materials, Mr. R. R. Kennedy read a Paper on "Creep Characteristics of Aluminium Alloys. We append his conclusions.

Caution should be used in applying the results of creep tests to the design of aeroplane-engine parts due to the difference between test conditions and service conditions. In a creep test, both the load and the temperature are constant for the period of the test, while in an airplane engine the parts are subjected to vibration, often to alternating tensile and compressive stresses, while the temperature fluctuates according to operating conditions. The results of creep tests should be of value, however, in indicating the relative behaviour of the various alloys at operating temperatures.

Some correlation has been observed between creep characteristics and service performance in the case of air-cooled cylinder heads for aeroplane engines. These parts are cast from alloys Nos. 1 and 2, which have good creep characteristics. They have proven satisfactory in service and few failures have been reported. Recently, cylinder heads of the same type have been cast from alloy No. 8, which has poor creep characteristics. Many of these cylinder heads have failed during block tests of the engine. Alloy No. 8 has low heat conductivity, so these cylinder heads operate at temperatures approximately 50 deg. Fah. (28 deg. C.) higher than cylinder heads cast from alloys Nos. 1 and 2. The higher operating temperature would tend to lower the mechanical properties of the alloy, but it is probable that the high creep rate is an important factor in the failure of the cylinder heads.

The same correlation has not been observed in the cast aeroplane-engine pistons. These parts were formerly cast from alloys Nos. 1 and 2, but are now forged from alloys Nos. 5 and 7 which have poorer creep characteristics. The wrought alloys have given satisfactory service in spite of their high-creep rates. As in the case of the cylinder heads, a difference in operating temperature is probably a contributing factor, because, due to changes in piston design, the wrought pistons run cooler than do the cast pistons.

Table I.—*Chemical Composition and Heat-Treatment of Aluminium Alloys Used.*

Alloy.	Chemical composition. Per cent.						Solution treatment.*		Ageing treatment.	
	Copper.	Iron.	Silicon.	Magnesium.	Nickel.	Manganese.	Temperature.	Time, hrs.	Temperature.	Time, hrs.
No. 1†..	3.90	0.38	0.21	1.60	2.22	—	510 deg. C.	5	190 deg. C.	5
No. 1-A‡	3.91	0.35	0.13	1.68	2.22	—	510 ,,	5	190 ,,	5
No. 2†..	9.64	1.08	0.22	0.23	—	—	495 ,,	5	190 ,,	5
No. 3†..	1.18	0.26	4.61	0.58	—	—	525 ,,	16	225 ,,	8
No. 4†..	4.29	0.50	0.66	—	—	—	515 ,,	24	150 ,,	2
No. 5‡,§	0.90	0.78	12.64	0.96	0.91	0.02	—	—	—	—
No. 6‡,§	2.96	0.53	13.18	1.04	3.08	—	—	—	—	—
No. 7‡,§	4.06	0.62	0.21	0.47	2.12	0.01	—	—	—	—
No. 8†..	0.37	0.28	0.19	5.96	1.49	1.00	None	—	—	—

* Specimens quenched in cold water at conclusion of solution treatment. † Cast alloys. ‡ Wrought alloys. § Alloys supplied in heat-treated condition. Method of heat-treatment was not reported.

Company Meeting

Presiding at the annual meeting of Messrs. W. & T. Avery, Limited, held at Birmingham recently, Sir J. Fortescue Flannery, Bt. (chairman), said that steady progress had been experienced throughout the year and was still continuing. The weighing-machine industry had undergone rapid developments since he first became connected with it. In addition to the technicians and draughtsmen at Soho Foundry who were dealing with the current problems and day-to-day requirements, they had a large development section studying and designing to meet the needs of to-morrow, in conjunction with the developments which were taking place in industrial methods and processes. As regarded the means of production, large quantities of machine tools and plant had been ordered during the year and were being put into commission as opportunity offered. Many of their processes and methods had been completely redesigned. During the year they acquired the old-established business of Joshua Buckton & Company, Limited, and their goodwill for testing machinery had been brought in. The business of Parnall & Sons, Limited, had again shown progress, and its works at Bristol had been well employed.

At an extraordinary general meeting which followed, resolutions were passed giving effect to recommendations for the transfer of £100,000 from the reserves to a pensions fund, and for the capitalisation of £142,363, forming part of the general reserve fund, by the distribution among the holders of the issued ordinary shares of one new ordinary share of £1 for every five ordinary shares held.

Tungsten Plating

In discussing tungsten plating in "Metal Cleaning and Finishing," W. A. Koehler points out that this metal is in the same series as chromium in the periodic system. It has a bright silvery lustre, but, unlike chromium, it is not attacked by any of the common mineral acids, but can be dissolved by a mixture of nitric and hydrofluoric acids. A thick coating of metallic tungsten can be plated electrolytically and is especially valuable for covering baser metals in laboratory ware. The metal is not affected by sulphur or phosphorus. It has a hardness on Mohr's scale of about seven. The tungsten plating solution is easy to prepare. A saturated solution of sodium carbonate is made at 100 deg. C. and tungsten trioxide, WO_3, is added as long as the sodium tungstate formed is soluble. The solution is electrolysed usually at 75 amps. per sq. ft. and the higher the temperature the brighter the deposit. The solution is not entirely stable and will slowly deteriorate when used constantly.

XUM

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This Week's News in Brief

Trade Talk

MESSRS. HURST, NELSON & COMPANY, LIMITED, Flemington Works, Motherwell, have received an order for 12-ton coal wagons for the London County Council.

THE STEEL COMPANY OF SCOTLAND, LIMITED, Blochairn Works, Glasgow, has booked a large order for locomotive tyres for the Assam Bengal Railway Administration.

MESSRS. SWAN, HUNTER & WIGHAM RICHARDSON, LIMITED, Wallsend, have received an order from Messrs. Bullard King & Company for a cargo and passenger ship, 450 ft. long, to carry 8,800 tons.

OVER 5,000 WORKERS engaged in the heavy-steel section of the Scottish iron and steel industry will receive an increase of 5 per cent. in wages from to-day under the sliding-scale agreement. The rates will then be 28¾ above base rate.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, inform us that both their London office and the offices of their export company are moving from Bush House, and that on and from August 6, 1935, their London office address will be 1, Kingsway, London, W.C.2. The telegraphic address will be "Multiphase, Estrand, London," and the telephone number will remain unchanged.

DURING THE WEEK a large party of delegates—consisting of ladies and gentlemen from England, America, Poland, Italy, Switzerland, Holland, India and other countries—attending the International Congress for Scientific Management visited Messrs. Fredk. Braby & Company's Eclipse Iron and Steel Works at Petershill, Glasgow. The party showed great interest in the processes for the production of black and galvanised sheets, staircases, windows, panelling, flooring, cisterns, steel structural work and the making of metal-faced plywood. The party afterwards proceeded to Edinburgh.

A SPECIAL ELECTRODEPOSITION EXHIBITION at the Science Museum, South Kensington, was opened by Lord Melchett last Thursday. It has been designed to illustrate to the layman all the phases of electrodeposition and the scientific principles upon which it is based. It will remain open, free, to the public until the end of the month of October. The exhibition has been organised by the Electrodepositors' Technical Society and the Science Museum. Valuable help in its preparation has been given by the British Non-Ferrous Metals Research Association, the Research Department, Woolwich, the Royal Mint, and leading industrial firms.

SPEAKING AT A LUNCHEON in Cardiff, Mr. George Williams (chairman of the South Wales and Monmouthshire Industrial Development Council) said his information was that the new steelworks of the British (Guest Keen Baldwins) Iron & Steel Company, Limited, at East Moors, Cardiff, would employ an additional 2,000 men and about 9,000 tons of coal would be consumed every week throughout the year. He referred to misinformed statements which put difficulties in the way of attracting new industries to South Wales, and said that people called South Wales the home of industrial unrest. This move of the steelworks firm, however, was the first answer to that.

Obituary

MR. ANDREW L. DEAS, J.P., of Messrs. John Deas & Company, Limited, ironfounders and heating engineers, Sydney Street Ironworks, Glasgow, died recently. Mr. Deas was 64 years of age.

MR. JAMES GREENHALGH, of Dukinfield, who has died at the age of 94, was the oldest trade unionist in the world. He was a moulder, and joined the National Union of Foundry Workers in 1861, from whom he received superannuation for the past 34 years.

MR. ERNEST J. GRIFFITHS, secretary for many years of the Welsh Engineers' and Founders' Association, died last week, aged 60. He had not been well for the past three or four months, and a heart attack brought about his death. Mr. Griffiths, who was held in the highest esteem in the foundry trade of West Wales, was the hon. treasurer of the South Wales Province Masonic Benevolent Fund.

Personal

MR. THOMAS GOODWIN, of Borrowash, near Derby, has been elected a director of E. S. Lord, Limited, Rochdale.

MR. CHARLES THORNTON has been promoted general manager of Messrs. Dickson & Mann, Limited, founders, Bathgate, and Mr. James Harper succeeds him as works manager. Mr. David Adamson, who for over a long period of years has been in charge of the labourers, has retired.

ON THE OCCASION of his leaving to take up a new appointment at Lugar, Mr. D. L. McCardel, general manager of Messrs. Bairds & Dalmellington, Limited, was the recipient of a display cabinet from his staff and employees of the firm. Mr. McCardel will be succeeded by Mr. George W. Kirkwood.

MR. JAMES MARR, who is in his ninety-second year, and his brother, Mr. Henry J. Marr, who is in his eighty-eighth year, are still working as blacksmiths. They both began work when twelve years of age and served apprenticeships with their father. Mr. James Marr for a time went to work at Banff Foundry, but seventy years ago returned to the smithy, where he has worked ever since.

MR. H. S. VASSAR, laboratory engineer in charge of testing laboratory, Public Service Electric & Gas Company, Irvington, N.J., U.S.A., has succeeded Dr. von Schrenk as President of the American Society for Testing Materials; Prof. A. E. White, University of Michigan, was chosen Junior Vice-President to serve with Mr. A. C. Fieldner, U.S. Bureau of Mines, who became a Vice-President in 1934.

MR. V. WATLINGTON has been appointed director in charge of the activities of the British Electrical and Allied Manufacturers' Association. At its meeting held on July 18, the Council of the Association decided that the entire control of "Beama" management was to be vested in the one director. Mr. Watlington has been a joint director since 1932; he now assumes sole responsibility to the Council of the Association for all "Beama" activities. Mr. C. Rodgers, secretary of the Association since 1921, has been appointed deputy-director. Mr. Watlington has been associated with the "Beama" for a long time. He has from the earliest days been a working member of almost every important section, and has made a study, both intensive and extensive, of the whole of its machinery. He has been chairman of several committees, including the Revising Committee. He was appointed a member of the Council in 1925 and in March, 1929, was unanimously elected chairman. Mr. Watlington occupied the chair for three years until his appointment as joint director in 1932.

Wills

NEILSON, JOHN, of Glasgow, ironmaster	£154,765
CRITTALL, F. H., founder of the Crittall Manufacturing Company, Limited ...	£18,255
ANDERSON, J. T., of Falkirk, retired ironfounder	£6,115
WREAKS, J. H., of Llandudno, formerly of Sheffield, at one time lecturer in metallurgy in the University of Sheffield	£6,088

Contracts Open

Khartoum, August 15.—Centrifugal pumping plant and fittings, for the Egyptian Irrigation Department. The Department of Overseas Trade. (Reference T.Y. 5,085.)

Devizes, August 21.—25 miles of spun and cast-iron water mains, varying from 8 in. to 2 in. dia., for the Rural District Council. Messrs. Parker Pearson & Ross Hooper, Dallas Chambers, Chippenham, Wilts. (Fee £2, returnable.)

Lye, August 10.—Construction of 1,260 yds. of 9-in. cast-iron pipe sewer, for the Upper Stour Valley Main Sewerage Board. Mr. G. Plant Deeley, 13, Church Street, Stourbridge. (Fee £3 3s., returnable.)

Bridgwater, August 8.—360 yds. and 100 yds. of 27-in. dia. s. and s. concrete and steel pipe sewers respectively, and 180 yds. of 9-in. cast-iron pipe sewer, for the Town Council. Messrs. Sandford Fawcett & Partners, 53, Victoria Street, Westminster, S.W.1. (Fee £5 5s., returnable.)

Publication Received

Copper Data. The Copper Development Association, Thames House, Millbank, London, S.W.1, have performed a real service to the metallurgical and engineering industries by publishing a 64-page booklet which summarises the most frequently sought data germane to copper. By a happy coincidence it is roughly the same format as "Aluminium Facts," and these two books certainly place foundrymen in full possession of the fundamental data of two of their most important raw materials. The booklet has been divided into three main sections:—(1) the properties of copper; (2) treatment and working of copper, and (3) commercial grades and application. The first section which is sub-divided into the mechanical, electrical, and other physical properties including corrosion is, like those which follow, illustrated by several graphs. This is a distinctly useful feature as it eliminates a quantity of tabular matter. The second section covers such processes as hot and cold working, soldering, brazing, welding, and machinery. The third section, to our mind, is somewhat incomplete, as it fails to include the better-known foundry alloys as distinct entities, although a number of applications of such alloys are listed. In section II, however, reference is made to CDA Publication "Brasses I." We have referred to this and are confirmed in our opinion that the major portion of the material contained therein should have been included in the book under review, and the scope of the book usefully widened. However, there is at least some logic in separating copper and copper alloys. The book is jacketed in a copper-coloured back and bound by means of a copper-wire spiral. It is available to our readers gratis on application and we should advise them also to ask for "Brasses I" at the same time, as from the foundry point of view it is complementary.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

O. Carter (Brassfounders), Limited.—Capital £1,000. Director: O. Carter, 17, Longmore Road, Shirley, Warwickshire.

Joseph Trippett & Sons, Limited.—Capital £1,000. Steelcasters, ironfounders, etc. Permanent directors: C. W. Verity, 145, White Lee Road, Swinton, near Rotherham, and A. A. Verity.

Fluvario, Limited.—Capital £5,000. To acquire any invention relating to pumping machinery, etc. Directors: E. E. Guiness, Allendale, Coalway Road, Wolverhampton; R. C. Watts, M. Elwell, W. Elwell and H. A. Davies.

Supercast Foundry Company, Limited, "Whitehaven," Red House Road, Tettenhall, Staffs.—Capital £1,500. To take over the business of iron and steel founders carried on by R. Small and H. M. North at The Supercast Foundry, Meeting Street, Wednesbury. Directors: R. Small, H. M. North and C. R. H. Smith.

Imperial Magnesium Corporation, Limited.—Capital £200,000 in £1 shares (100,000 preferred ordinary and 100,000 deferred). The Imperial Smelting Corporation, Limited, the British Aluminium Company, Limited, Magnesium Metal & Alloys, Limited, and Imperial Chemical Industries, Limited, are each to appoint one-fourth of the directors.

Welded Battleships

According to "The Times" Paris Correspondent, the "pocket battleships" of the Deutschland class, which were electrically welded, have shown serious defects, due, it is believed, to the vibration from the Diesel engines. Germany, it is said, is to return to normal riveted-built structures and steam propulsion.

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MOULDS AT LEAST 50% QUICKER THAN PREVIOUS METHODS.

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Raw Material Markets

Although the volume of business in the iron and steel trade continues to be above the average for the time of the year, conditions have quietened down a little during the last week. The holidays are the chief cause of this slackening of business. Hematite prices have been further revised, and a zoning scheme and co-ordinated scales of prices, fixed according to the geographical position of the consumers' works, is being formulated following further meetings between the East and West Coast and Welsh manufacturers.

Pig-Iron

MIDDLESBROUGH.—The output of pig-iron in the Cleveland area is increasing, and in all probability one or two more blast furnaces will be relighted in the near future. Consumption in the district is very heavy, and iron is still being sent to some of the foundries from the Midlands. Scottish specifications are increasing, as the light-castings trade is very much more active than for some time past. An increase in the price of foundry iron is believed likely, and this report caused consumers to extend their contracts before an alteration occurred. No change has yet been made, however, and minimum quotations for No. 3 Cleveland G.M.B. are still 67s. 6d. per ton delivered Middlesbrough, 69s. 6d. delivered North-East Coast, 67s. 3d. delivered Falkirk, and 70s. 3d. delivered Glasgow. An additional half-crown per ton is charged for No. 1 foundry, and 1s. per ton less than the given prices for No. 3 is asked for No. 4 forge and No. 4 foundry. The complete revised scale of prices for East Coast hematite is not yet available, as it is still to be formally ratified. It is understood that in the various producing areas on the East and West Coasts and in South Wales, the local delivered price of No. 1 hematite will be 71s. per ton, and the prices for other districts will be fixed by adding transport charges to consumers' works. Under this scheme the delivered price of No. 1 East Coast hematite on the Tyne will be 72s.: in the remainder of Durham and Northumberland 73s. 6d.; in Sheffield and the No. 2 Yorkshire zone 78s. 6d.; and in other districts 80s. to 87s. per ton. New contracts will all be fixed under this scale, but there are still numerous orders to be delivered under the old system of prices.

LANCASHIRE.—New business has been entered into between consumers and manufacturers of common irons during the last week in a very substantial manner. Machine-tool makers, the light-castings trade, and the heavy electrical trade all report satisfactory conditions. Rather better conditions are reported from the general engineers and jobbing founders. Derbyshire, Staffordshire and Lancashire brands of No. 3 foundry iron equal to Derbyshire are all quoted for delivery to users in the Lancashire price zone on the basis of 74s. per ton, with Northamptonshire at 72s. 6d., Scottish foundry at from 81s. 6d. to 82s. 6d., West Coast hematite at around 81s., and East Coast at from 77s. 6d. to 78s. 6d. per ton, according to grade.

MIDLANDS.—Quieter conditions prevail on this market following an active period, most consumers of pig-iron being now well covered forward. No changes have occurred in the controlled prices for Midland foundry iron. Light founders are better employed than was the case recently, and the jobbing and general engineering foundries are taking good quantities of pig-iron. The quotation for Scottish No. 3 iron in this district is 85s., low-phosphorus iron varies in price between 85s. to 90s., and medium-phosphorus irons vary from 72s. to 80s. Refined iron ranges from £5 7s. 6d. to £7, delivered the Midlands. The price of West Coast hematite, surprisingly, is back on the old basis of 84s. 6d., while East Coast and Welsh hematites are at 80s. 6d. Common irons are at 67s. 6d. for Northants No. 3 and 71s. for Derbyshire, Lincolnshire and South Staffordshire No. 3.

SCOTLAND.—Conditions are still quiet on this market. Scottish iron prices remain unchanged on the week. Falkirk founders have now completely resumed and business is on a satisfactory scale. No change is noted in the prices of Cleveland iron at 67s. 3d. at Falkirk and 70s. 3d. at Glasgow, and other English irons are 1s. 3d. per ton less. Local steelworks have good prospects after the holidays except from shipbuilding sources, which are quiet. Steelmaking iron quotations are:—Mixed numbers Scottish hematite 71s., ordinary mixed numbers West Coast hematite 75s., ordinary mixed numbers East Coast hematite 77s. 6d., basic, British and Indian, 70s., less 5s. rebate, all delivered Scottish steelworks.

Coke

There have been few inquiries for foundry coke and conditions are still very quiet. Durham foundry coke realises 20s. to 21s. f.o.r. ovens. For delivery in the Birmingham district prices are:—Best Durham coke, 34s. to 40s.; Welsh, 31s. to 42s. 6d.

Steel

The usual midsummer trading conditions rule in the steel market, but there is still a fair volume of business passing in some departments. Business in the semi-finished steel section of the market has not been active, but the demand has been steady and the decline in consumers' requirements which generally takes place at this time of the year has not been noticeable. The majority of the important users are well covered, and most of the business which has taken place recently has been limited to small parcels. The producing works, however, have a large tonnage of orders on their books and are making heavy deliveries. The active conditions which have ruled for some weeks in the finished-steel department have been well maintained. With the exception of heavy steel plates, the demand for practically all classes of finished steel is exceptionally strong for this season, and shows no signs of declining. The works are well provided with orders and can look forward to busy conditions for some months. The bulk of the work in hand is on home account, but lately the requirements of oversea markets have shown signs of expanding.

Scrap

In the Cleveland market large quantities of good heavy melting steel are being sold at 52s. 6d. per ton delivered works. Foundry cast iron is at the same price and an increase is anticipated. Clean light cast iron is active again and is between 43s. and 44s. and cast-iron borings are at 25s. per ton delivered works. The South Wales market is still very quiet. Heavy cast iron in large pieces and furnace sizes is at 50s. to 52s., and good machinery scrap at 52s. 6d. to 55s. Buying on the Midland market has been restricted. Heavy steel in furnace sizes is at 44s. to 45s. and mixed heavy iron and steel at 42s. 6d. to 43s. 6d. Heavy steel turnings are easy at 34s. Heavy wrought iron remains steady at 57s. 6d. and clean cast-iron borings at 30s. Heavy cast-iron machinery scrap in cupola sizes is at 55s. to 57s. 6d., good heavy at 50s. and clean light at 47s. 6d., delivered works.

Metals

Copper.—It was expected that a reaction would occur in the price of copper, but the fall has been a little greater than was anticipated. Following the mid-month excitement, the market has quietened considerably, due, perhaps, to the summer period. Favourable news comes from the United States, where, in spite of a very large demand during the second week of July, buying still continues.

Daily market prices:—

Cash.—Thursday, £31 10s. to £31 11s. 3d.; Friday, £31 to £31 2s. 6d.; Monday, £31 6s. 3d. to £31 7s. 6d.; Tuesday, £31 6s. 3d. to £31 7s. 6d.; Wednesday, £31 8s. 9d. to £31 11s. 3d.

Three Months.—Thursday, £31 17s. 6d. to £31 18s. 9d.; Friday, £31 8s. 9d. to £31 10s.; Monday, £31 15s. to £31 16s. 3d.; Tuesday, £31 13s. 9d. to £31 15s.; Wednesday, £31 17s. 6d. to £32.

Tin.—Business in this metal has been of a very restricted nature, and it seems as though confidence in tin has weakened. The demand for the metal for trade purposes is of a hand-to-mouth character, the unsettled condition of Continental currency having the effect of disorganising transactions. At the same time, owing to the strict control exercised, prompt supplies remain short, and it is considered that an early addition to quotas, preferably retrospective to July 1, is necessary in order to prevent any worsening of the present stringency.

Day-to-day fluctuations:—

Cash.—Thursday, £229 to £231; Friday, £230 10s. to £234; Monday, £233 15s. to £234; Tuesday, £233 15s. to £234; Wednesday, £233 12s. 6d. to £233 15s.

Three Months.—Thursday, £220 to £220 10s.; Friday, £220 to £220 10s.; Monday, £219 to £219 10s.; Tuesday, £219 to £219 10s.; Wednesday, £218 15s. to £219.

Spelter.—The price of this metal became lower towards the end of last week in sympathy with the other metals. On Monday the price increased 5s., and the position of spelter is fairly satisfactory, although it is still not so strong as lead. A firm tone is again reported from the American market, an increase in price being chiefly due to the more encouraging outlook of the brass mills.

Official quotations were as follow:—

Ordinary.—Thursday, £14 8s. 9d.; Friday, £14 3s. 9d.; Monday, £14 8s. 9d.; Tuesday, £14 5s.; Wednesday, £14 3s. 9d.

Lead.—During the past week the price of lead has fluctuated in an erratic manner. However, the situation on the whole continues to be sound. Although the demand for lead will, in all probability, slacken over the August Bank holiday, consumption remains strong, and there is no reason why this should not continue to be so. A fairly steady market is reported from the United States, where pipes and sheets have given continued activity in the building trade. The world production of lead during June, as reported by the American Bureau of Metal Statistics, was 122,200 tons, compared with 135,100 tons in May. Production in America amounted to 29,300 tons, against 33,200 tons during May.

Day-to-day quotations:—

Soft Foreign (Prompt).—Thursday, £15; Friday, £15 2s. 6d.; Monday, £15 3s. 9d.; Tuesday, £15 2s. 6d.; Wednesday, £15 7s. 6d.

Company Reports

Platt Bros. & Company (Holdings), Limited.—The directors have decided to pay the arrears of dividend on the 4½ per cent. preference shares in respect of the half-year ended September 30, 1933.

Vickers, Limited.—Interim dividends for the half-year ended June 30 last of 2½ per cent., less tax, on the preferred 5 per cent. stock, 2½ per cent., less tax, on the 5 per cent. preference shares, and 2½ per cent., free of tax, on the cumulative preference shares.

Copper in Malleable and Grey Cast Iron

The Battelle Memorial Institute undertook to determine the properties of copper-alloyed grey and malleable cast iron with these results:—In grey irons, copper increases the tensile and transverse strengths and the hardness, there being no diminishing in its effect up to at least 4 per cent. Irons alloyed with both copper and nickel were equal in properties to the copper or the nickel irons of the same total alloy content. Copper has a mild effect in reducing chill. In malleable iron, copper speeds up the graphitisation, raises the tensile and particularly the yield strength, increases the hardness, modifies the galvanising embrittlement effect, promotes corrosion resistance, and makes the iron amenable to precipitation hardening. Since it retards the rate of transformation, copper assists in the heat-treatment of grey or malleable iron by retaining certain structural features, obtained in unalloyed irons only on rapid quenching, at much reduced rates of quenching.—"Mining and Metallurgy."

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MOULDING BOXES

ARE THE GREATEST ECONOMY
YOU CAN INTRODUCE INTO
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THEY SPEED UP PRODUCTION
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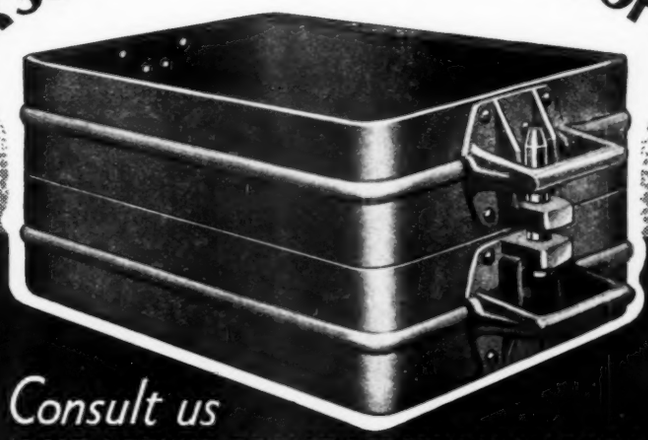
SAVE UNNECESSARY LABOUR

OVER 30 STANDARD DESIGNS OF BOXES



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STERLING FOUNDRY SPECIALTIES LTD
BEDFORD
LONDON OFFICE: 13 VICTORIA STREET · WESTMINSTER S.W.1

RAW MATERIALS—PRICE LIST

(Wednesday, July 31, 1935)

COPPER

	£	s.	d.
Standard cash	31	8	9
Three months	31	17	6
Electrolytic	34	15	0
Tough	32	15	0
Best selected	33	5	0
Sheets	62	0	0
India	44	10	0
Wire bars	34	15	0
Ingot bars	34	15	0
H.C. wire rods	38	10	0
Off. av. cash, June	30	16	8 1/10
Do., 3 mths., June	31	4	1 1/10
Do., Sttlmnt., June	30	16	10 3/10
Do., Electro, June	34	7	4 6/10
Do., B.S., June	33	13	1 1/2
Do., wire bars, June	34	13	11 7/10
Solid drawn tubes			10d.
Brazed tubes			10d.
Wire			6d.

BRASS

Solid drawn tubes	9 1/2d.
Brazed tubes	11 1/2d.
Rods, drawn	8d.
Rods, extd. or rlld.	4 1/2d.
Sheets to 10 w.g.	7 1/2d.
Wire	7 3/4d.
Rolled metal	7d.
Yellow metal rods	4 1/2d.
Do. 4 × 4 Squares	5 1/2d.
Do. 4 × 3 Sheets	5 3/4d.

TIN

	£	s.	d.
Standard cash	233	12	6
Three months	218	15	0
English	233	10	0
Bars	235	15	0
Straits (nom.)	238	12	6
Australian (nom.)	234	2	6
Eastern	231	7	6
Banca (nom.)	235	15	0
Off. av. cash, June	227	14	3 6/10
Do., 3 mths., June	219	10	9 9/10
Do., Sttlmt., June	227	14	5 1/10

SPELTER

	£	s.	d.
Ordinary	14	3	9
Remelted	14	10	0
Hard	11	10	0
Electro 99.9	16	13	9
English	15	5	0
India	13	0	0
Zinc dust	18	10	0
Zinc ashes	3	5	0
Off. aver., June	13	16	3 1/10
Aver. spot, June	13	14	8 1/10

LEAD

	£	s.	d.
Soft foreign ppt.	15	7	6
Empire (nom.)	16	5	0
English	17	5	0
Off. average, June	13	15	9 13/20
Average spot, June	13	15	6 9/10

ALUMINIUM

Ingots	£100 to £105
Wire	1/1 to 1/9 lb.
Sheet and foil	1/2 to 2/9 lb.

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	22	0	0
Do., V.M. ex-whse.	23	10	0
Rods	28	17	6

ANTIMONY

	£	s.	d.		£	s.	d.
English	74	0	0	to 75	0	0	
Chinese, ex-whse.					69	0	0
Crude, c.i.f.					27	10	0

QUICKSILVER

Quicksilver	11 2 6 to 11 12 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
23/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£15 15 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 10 0
4/6% car.	21 15 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	34 0 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70%, carbon-free	9 1/2d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	5/6 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£10 15 0 to 11 5 0
76/80% packed	£11 15 0 to 12 5 0
76/80% export	(nom.) £9 15 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under 1/2 in. to 1/4 in.	3d. lb.
Do., under 1/4 in. to 7/16 in.	1/- lb.
Flats, 1/2 in. × 1/4 in. to under 1 in. × 3/8 in.	3d. lb.
Do., under 1/4 in. × 1/4 in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£	s.	d.		£	s.	d.
South Wales—							
Heavy steel	2	15	0	to 2	16	0	
Bundled shrngs.	2	7	6	to 2	15	0	
Mixed iron and steel	2	10	0	to 2	12	0	
Heavy cast iron	2	10	0	to 2	12	0	
Good machinery	2	12	6	to 2	15	0	
Cleveland—							
Heavy steel				2	12	6	
Steel turnings				1	15	0	
Cast-iron borings				1	5	0	
Heavy cast iron				2	12	6	
Heavy machinery	2	14	0	to 2	15	0	
Midlands—							
Light cast-iron scrap				2	7	6	
Heavy wrought iron				2	17	6	
Steel turnings				1	14	0	
Scotland—							
Heavy steel				2	10	0	
Ordinary cast iron				2	12	6	
Engineers' turnings				1	19	6	
Cast-iron borings	1	17	6	to 1	19	0	
Wrot-iron piling				2	17	6	
Heavy machinery				2	17	6	

London—Merchants' buying prices, delivered yard.

	£	s.	d.
Copper (clean)	27	0	0
Brass	17	0	0
Lead (less usual draft)	13	0	0
Tea lead	9	12	0
Zinc	8	10	0
New aluminium cuttings	66	0	0
Braziery copper	23	0	0
Gunmetal	25	0	0
Hollow pewter	160	0	0
Shaped black pewter	120	0	0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	70/-
Foundry No. 3	67/6
,, at Falkirk	67/3
,, at Glasgow	70/3
Foundry No. 4	66/6
Forge No. 4	66/6
Hematite No. 1	71/-
Hematite M/Nos.	70/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	75/-
,, d/d Birm.	84/6
Malleable iron d/d Birm.	115/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	67/-
,, No. 3 fdry.	71/-
Northants forge	63/6
,, fdry. No. 3	67/6
,, fdry. No. 1	70/6
Derbyshire forge	67/-
,, fdry. No. 3	71/-
,, fdry. No. 1	74/-
Scotland—	
Foundry No. 1, f.o.t.	72/6
,, No. 3, f.o.t.	70/-
Hem. M/Nos. d/d	71/-
Sheffield (d/d district)—	
Derby forge	64/6
,, fdry. No. 3	68/6
Lincs forge	64/6
,, fdry. No. 3	68/6
W.C. hematite	86/-
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	74/-
Staffs fdry. No. 3	74/-
Northants fdry. No. 3	72/6
Cleveland fdry. No. 3	74/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	82/-
Clyde, No. 3	82/-
Monkland, No. 3	82/-
Summerlee, No. 3	82/-
Eglinton, No. 3	82/-
Gartsherrie, No. 3	82/-
Shotts, No. 3	82/-

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£	s.	d.		£	s.	d.
Bars (cr.)	9	12	6	to 9	15	0	
Nut and bolt iron	7	10	0	to 8	0	0	
Hoops	10	10	0	and up.			
Marked bars (Staffs) f.o.t.		12	0	0			
Gas strip		10	10	0	and up.		
Bolts and nuts, 3/4 in. × 4 in.		14	2	6	and up.		
Steel—							
Plates, ship, etc.	8	15	0	to 8	17	6	
Boiler plts.	9	5	0	to 9	7	6	
Chequer plts.				10	7	6	
Angles				8	7	6	
Tees				9	7	6	
Joists				8	15	0	
Rounds and squares, 3 in. to 5/8 in.				9	7	6	
Rounds under 3 in. to 1/4 in. (Untested)				8	12	0	
Flats—8 in. wide and over				8	12	6	
,, under 8 in. and over 5 in.				8	17	6	
Rails, heavy	8	5	0	to 8	10	0	
Fishplates	12	5	0	to 12	10	0	
Hoops (Staffs)				9	7	0	
Black sheets, 24g. (4-t. lots)				11	0	0	
Galv. cor. shts. (,,)				13	0	0	
Galv. flat shts. (,,)				13	10	0	
Galv. fencing wire, 8g. plain				14	10	0	
Billets, soft		5	10	0	and up.		
Billets, hard	6	17	6	to 7	2	6	
Sheet bars	5	2	6	to 5	7	6	
Tin bars	5	5	0	to 5	7	6	

PHOSPHOR BRONZE

	Per lb. basis.
Strip	9 1/2d.
Sheet to 10 w.g.	11 1/2d.
Wire	12d.
Rods	11d.
Tubes	13 1/2d.
Castings	12d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1 1/2 to 1/7 1/4
To 15 in. wide	1/1 1/2 to 1/7 1/2
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2 1/2 to 1/8 1/2
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3 1/2
Ingots rolled to spoon size	10d. to 1/6 1/2
Wire round—	
to 10g.	1/4 1/2 to 1/11 1/2

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3 1/2 upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	20.31
No. 2 foundry, Valley	18.50
No. 2 foundry, Birm.	14.50
Basic, Valley	18.00
Malleable, Valley	18.50
Grey forge, Valley	18.00
Ferro-mang. 80%, seaboard	85.00
O.-h. rails, h'y, at mill	36.37 1/2
Billets	27.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.80
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.70
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.60
Plain wire	2.30
Barbed wire, galv.	3.00
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 30/-
,, furnace	19/- to 20/-
Durham foundry	20/- to 21/-
,, furnace	16/6 to 17/9
Scotland, foundry	28/-
,, furnace	25/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20 × 14	per box	18/2 and up.
,,	28 × 20	,,	36/4 and up.
,,	20 × 10	,,	26/-
,,	18 1/2 × 14	,,	18/9
C.W.	20 × 14	,,	15/3 to 15/6
,,	28 × 20	,,	32/6 to 33/-
,,	20 × 10	,,	23/- to 23/3
,,	18 1/2 × 14	,,	15/6 to 15/9

SWEDISH CHARCOAL IRON & STEEL

	£	s.	d.		£	s.	d.
Pig-iron	6	0	0	to	7	0	0
Bars-hammered, basis	16	0	0	to	16	10	0
Bars and nail-rods, rolled, basis	15	15	0	to	16	0	0
Blooms	10	0	0	to	12	0	0
Keg steel	30	0	0	to	31	0	0
Faggot steel	18	0	0	to	23	0	0
Bars and rods dead soft, st'l	10	0	0	to	12	0	0

All per English ton, f.o.b. Gothenburg
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

	£	s.	d.	
July 25 ..	31	10	0	dec. 6/3
„ 26 ..	31	0	0	„ 10/-
„ 29 ..	31	6	3	inc. 6/3
„ 30 ..	31	6	3	No change
„ 31 ..	31	8	9	inc. 2/6

Electrolytic Copper

	£	s.	d.	
July 25 ..	34	15	0	dec. 5/-
„ 26 ..	34	10	0	„ 5/-
„ 29 ..	34	10	0	No change
„ 30 ..	34	10	0	„ „
„ 31 ..	34	15	0	inc. 5/-

Standard Tin (cash)

	£	s.	d.	
July 25 ..	229	0	0	dec. 85/-
„ 26 ..	230	10	0	inc. 30/-
„ 29 ..	233	15	0	„ 65/-
„ 30 ..	233	15	0	No change
„ 31 ..	233	12	6	dec. 2/6

Tin (English ingots)

	£	s.	d.	
July 25 ..	230	0	0	dec. 75/-
„ 26 ..	234	0	0	inc. 80/-
„ 29 ..	234	0	0	No change
„ 30 ..	233	15	0	inc. 5/-
„ 31 ..	233	10	0	dec. 5/-

Spelter (ordinary)

	£	s.	d.	
July 25 ..	14	8	9	dec. 6/3
„ 26 ..	14	3	9	„ 5/-
„ 29 ..	14	8	9	inc. 5/-
„ 30 ..	14	5	0	dec. 3/9
„ 31 ..	14	3	9	„ 1/3

Spelter (Electro, 99.9 per cent.)

	£	s.	d.	
July 25 ..	16	18	9	dec. 7/6
„ 26 ..	16	13	9	„ 5/-
„ 29 ..	16	18	9	inc. 5/-
„ 30 ..	16	15	0	dec. 3/9
„ 31 ..	16	13	9	„ 1/3

Zinc Sheets (English)

	£	s.	d.	
July 25 ..	22	10	0	dec. 10/-
„ 26 ..	22	5	0	„ 5/-
„ 29 ..	22	5	0	No change
„ 30 ..	22	0	0	dec. 5/-
„ 31 ..	22	0	0	No change

Lead (English)

	£	s.	d.	
July 25 ..	17	0	0	dec. 5/-
„ 26 ..	17	5	0	inc. 5/-
„ 29 ..	17	5	0	No change
„ 30 ..	17	5	0	„ „
„ 31 ..	17	5	0	„ „

AVERAGE MONTHLY PRICES OF WEST COAST HEMATITE MIXED NUMBERS DELIVERED SHEFFIELD

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1896	47 0	48 9	48 9	48 2½	47 3	47 3	46 10	46 10	47 2	48 5	50 7	50 6	48 1½
1897	51 2	49 10	48 5	47 4	47 9½	48 6	47 0	47 3	47 3	47 0	48 3½	47 11	48 2
1898	48 9	48 10	49 4	49 8½	50 10	50 3½	51 0	52 5	53 11	55 8	57 3	56 10	52 1½
1899	59 1	59 9	57 7	59 6	64 7	70 10½	76 7½	72 2	74 3	75 0	78 1½	73 3	68 5
1900	75 3½	76 10	79 10	84 6	81 4	79 1½	83 4	81 5	79 11	76 10	77 8½	68 4	78 8
1901	60 2	59 0	57 9½	57 6½	57 8	57 4½	57 8	61 0	60 0½	59 9	58 7½	56 7	58 7½
1902	56 1	57 9½	59 3½	59 9	59 10½	60 0	60 0	60 8½	61 5	61 2	59 3	59 0	59 6
1903	58 5	58 8	61 1	59 5	57 10	57 3	56 7	56 3	55 9	54 8	52 4	52 4	56 8½
1904	52 8½	53 1	53 7	54 9	54 2	53 2½	52 9	52 5	52 2½	52 7	53 1	55 11½	53 5½
1905	57 9½	56 9	58 1	58 2	56 4	55 8	55 5½	56 7	61 0	68 9	69 9	70 11½	60 5½
1906	70 4½	65 2½	63 4½	63 9	64 5	64 6	64 1	66 2½	67 3	69 4½	72 4½	78 8½	67 5
1907	77 9	72 11	71 10	73 9	79 9½	76 9	77 9	78 4	75 11	72 9½	68 6	66 7	74 4
1908	62 7	59 1	61 6½	61 6½	61 4	59 1	57 9½	56 11	60 2	59 2	58 5½	57 7	59 7½
1909	51 4	56 5	55 3	56 1	56 4	57 0	56 8	58 0	61 0	61 1½	60 7½	61 4	58 1½
1910	64 0½	64 3½	66 10½	67 6½	66 2½	65 4	64 4½	65 6½	65 2	64 10½	64 6	65 6	65 4½
1911	66 9	66 1	64 10	63 1	62 1	62 0	61 2	62 2	62 1	61 1	61 10	64 0	63 1
1912	67 0	67 0	67 0	69 3	71 9½	72 11	75 9½	79 1½	82 2½	85 0	85 3½	86 6	75 9½
1913	86 6	86 6	86 3	85 0	83 6½	80 10½	78 1	76 10½	72 6	71 0	68 0	65 3	78 4½
1914	64 6	65 4½	65 6	64 11½	64 2½	64 0	64 0	68 11½	74 6½	71 0	65 4½	69 9½	66 10½
1915	78 9	100 6	103 1	113 6	111 9	114 0	116 3	115 2½	113 8½	121 1½	131 9½	139 6½	113 3
1916	135 0	135 0	133 4	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	129 2½
1917	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1918	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1919	127 6	127 6	127 6	127 6	180 6	184 3	195 4½	204 6	204 6	204 6	204 6	204 6	174 7
1920	224 9	235 0	245 0	275 0	290 0	295 0	295 0	295 0	295 0	295 0	295 0	280 0	284 11½
1921	263 4	228 4	180 0	180 0	180 0	160 0	160 0	157 6	142 0	128 6	121 0	115 6	167 9½
1922	125 0	117 6	115 0	115 0	115 0	115 0	113 1½	104 0	105 0	105 0	106 3	110 0	112 1
1923	109 0½	116 5½	133 11½	138 3½	134 2	125 0	115 7½	111 9	110 0	110 0	113 11	115 0	119 5½
1924	115 0	115 0	114 4½	112 6	112 6	112 6	111 0	110 0	110 0	105 4½	102 6	102 6	110 3½
1925	102 6	102 6	100 0	98 6	97 6	95 1½	92 6	90 6	88 3	87 0	88 1½	88 9½	94 3½
1926	90 1½	90 0	89 8½	89 0	89 0	89 0	90 2½	91 9	94 0	97 2½	*	*	91 0
1927	95 4½	95 6	96 6	95 6	95 3	94 0	92 10½	91 6	90 6	90 6	90 6	89 6	93 1½
1928	85 0	85 3	85 5	85 0	85 3	84 9	84 0	83 9	84 0	84 0	83 1	82 6	84 4
1929	82 10½	83 6	85 0	86 9	87 0	87 0	87 3	87 2½	87 6	89 6	89 6	89 10½	86 11
1930	91 6	91 6	91 6	90 0	89 7½	88 0	87 7½	86 6	86 6	86 6	86 6	86 6	88 0½
1931	86 6	84 6	84 6	84 6	84 6	82 6	82 6	81 6	81 6	83 6	83 6	83 6	83 7
1932	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6
1933	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6
1934	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6	83 6
1935	83 6	83 6	83 6	83 6	83 6	83 6	85 4½	—	—	—	—	—	—

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